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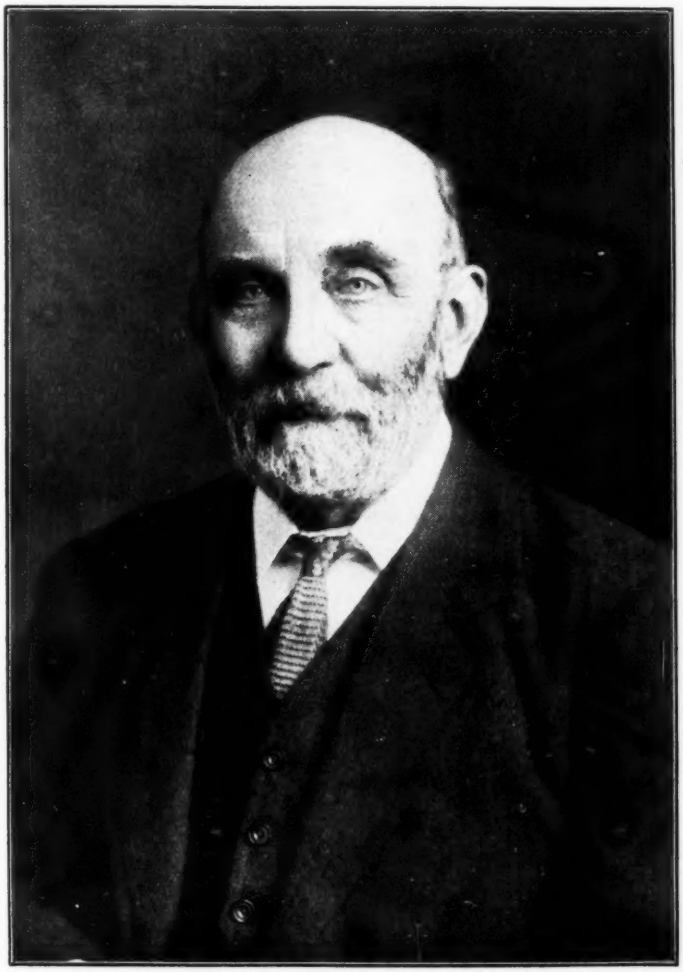
The Iron and Steel Institute.

Annual Meeting in London.

The annual meeting of the Iron and Steel Institute was opened at the hall of the Institution of Civil Engineers, Great George Street, Westminster, London, S.W., yesterday (Thursday). The retiring President (Mr. Eugene Schneider) occupied the chair at the outset. The Report of the Council, of which the following is an abstract, was submitted.



DR. J. E. STEAD. (*President of the Iron and Steel Institute.*)

REPORT OF COUNCIL.

The Council have pleasure in submitting to the members of the Iron and Steel Institute at this, the Fifty-

first Annual General Meeting, their Annual Report of the progress and work of the Institute during the year 1919.

Roll of the Institute.—At the autumn meeting it was announced that His Royal Highness the Prince of Wales had been graciously pleased to accept Honorary Membership. During the year there were 153 new members and 14 associates elected. Eight associates were also transferred from the Class of Associates to full membership. The total membership of the Institute on December 31, 1919, was: Patron, 1; Honorary Members, 4; Life Members, 75; Ordinary Members, 2,040; Associates, 61; total, 2,181. There were twenty-one resignations of membership during 1919, and the names of four members have been removed from the list owing to non-payment of subscriptions. During the year the deaths of thirty members were reported.

Honours Conferred Upon Members of the Institute.—Mr. Eugene Schneider, late President, has been awarded the Cross of an Officer of the Legion of Honour; also on the occasion of his recent mission to the United States he was elected an Honorary Member of the American Iron and Steel Institute. He received the honorary degree of Doctor of Science of the Universities of Pittsburgh and Cleveland and of Doctor of Engineering of the Stevens Institute of Technology, and had conferred upon him the Freedom of the City of Pittsburgh. He also received the Gold Medal of the American Institute of Mining and Metallurgical Engineers. Colonel John Roper Wright has been created a baronet. Mr. Christopher T. Needham has had the honour of knighthood conferred upon him. Mr. H. Dennis Bayley and Mr. T. Harris Spencer have been created Knights Commanders of the Order of the British Empire. Major W. Burnyeat has been awarded the Distinguished Service Order. General R. K. Bagnall-Wild has received the Order of the Cross of St. Michael and St. George. Mr. C. J. MacGuckin, Dr. A. McWilliam, and Mr. R. P. Sloan have had conferred upon them the Commandership of the Order of the British Empire, and the following have been created Officers of that Order: Captain C. A. Ablett, Mr. H. Bates, Lieut.-Colonel J. G. Needham, D.S.O., Captain P. W. Smith, and Mr. Frank Somers. The Freedom of the Blacksmiths' Company has been conferred on Mr. Eugene Schneider and on Sir William Beardmore, Bart., Past Presidents.

Finance.—The accounts show that the total receipts of the Institute during the year under review, excluding the income derived from the Carnegie Research Fund, were £5,979. The expenditure for the same year was £7,088, thus revealing a deficit on the accounts for the year 1919, of £1,109. Comparative figures for recent years are as follows:—

	Income.	Expenditure.
1914	£5,310	£4,701
1915	4,816	4,275
1916	4,767	4,208
1917	5,427	5,202
1918	5,792	6,128

Notwithstanding that the income has exceeded that of any previous year in the history of the Institute, it has unfortunately been insufficient to meet the increased expenditure, due principally to the greatly enhanced cost of printing and publishing the "Journal." In these circumstances it has been found necessary partly to meet the deficit by realising some of the invested funds of the Institute, and £1,000 of 5 per cent. War Stock (1929-1947) was sold for this purpose, the balance being met by a temporary advance from the accumulated income of the Carnegie Scholarship Fund. War Loan Stock to the amount of £1,000 has since been transferred from the invested funds of the Institute in part discharge of this advance. The whole situation has had the careful consideration of the Council, who appointed Mr. Ilktyd Williams (Hon. Treasurer), Mr. Steer, Mr. Rylands, and Mr. Harbord a Finance Committee to deal with the matter. Acting on the recommendations of this Committee, the Council have now under consideration the question of raising the annual subscription. As, however, no such action can become operative without amending the Bye-Laws, and as no resolution thereto can take effect before 1922, the Council have had recourse to an appeal to the members voluntarily to increase the amount of their subscriptions in the current year, an expedient which it is hoped may, in the interim, enable the Institute to meet the deficiency which it is anticipated will again occur in the forthcoming twelvemonth.

The income of the Carnegie Research Scholarship during 1919 was £1,018, and the expenditure was £525. The surplus income over expenditure was therefore £493.

Special Fund.—In April, 1919, the Council invited the iron and steel makers of the United Kingdom to subscribe to a Special Fund, the interest on which should be applied to the extension of the work of the Institute, and of the various technical committees formed to promote metallurgical practice, and to assist by donations and annual subscriptions educational schemes for scientific, technical, and industrial training. In response to this appeal a sum of £11,036 was subscribed, of which £7,616 was actually received before the end of the year, with promises of a further £3,420 during the next two years.

Committee Work.—During the year a number of meetings have been held by the Technical Committees appointed in 1917. The Sub-Committee on the Production of Sound Steel has delegated to Mr. F. W. Harbord, C.B.E., the collection of details of the various processes extant for the manufacture of sound ingots, and an interim report has been received from Mr. Harbord, which will be duly considered by the Committee.

The Sub-Committee on Standard Steels has held three meetings, two in London and one in Sheffield. Standard steel ingots have now been selected by five of the district authorities as follows:—Middlesbrough (carbon, 0.1 per cent.); North Midlands (carbon, 0.66 per cent.); Glasgow (sulphur, 0.03 per cent.); South Wales (sulphur, 0.07 per cent.); Birmingham (phosphorus, 0.076 to 0.080 per cent.). The North Midland (Sheffield) authority's selected ingot has been sent to Teddington for ultimate check analyses and preparation of standards.

Appointment of Representatives.—The President continued to represent the Institute on the General Committee of the Royal Society for administering the Government Grant for Scientific Investigations. Sir W. H. Ellis, G.B.E., and Prof. Henry Louis represent the Institute on the Board of the National Physical Laboratory, and Sir Hugh Bell, Bart., continues to act as representative on the Board of Governors of the Imperial College of Science and Technology. On the British Engineering Standards Association the Institute is represented by Dr. Arthur Cooper and Mr. Ilktyd Williams, and Mr. Charles Dorman continues to serve on the Engineering Standards Sub-Committee for the Standardisation of Galvanised Sheets, and Mr. R. E. E. Spencer on the Sub-Committee for Special Steels for Motor-Car Construction. Mr. H. J. Yates has been appointed to serve on the Sub-Committee for Cast Iron, working under the direction of the Sectional Aircraft Committee. Sir William Beardmore, Bart., represents the Institute on the Technical Committee of "Lloyd's Register of British and Foreign Shipping," and Mr. J. H. S. Dickenson represents the Institute on the Technical Committee of Motor Industries. Sir Hugh Bell and Prof. Henry Louis (acting *pro tem.*, on behalf of Sir Charles Allen) represent the Institute on the Board of Scientific Societies of the Royal Society. Dr. Arthur Cooper was appointed to represent the Institute on the Council of the Engineering Training Organisation. Sir Robert Hadfield, Bart., represents the Institute on the British Association Fuel Economy Committee. Sir Robert Hadfield has also represented the Institute on the Court of Sheffield University. Mr.

W. Peter Rylands on the Court of Liverpool University and Mr. W. R. Lysaght, C.B.E., on the Court of the University of Bristol. Mr. F. W. Harbord, C.B.E., represents the Institute on the Advisory Board of the Royal School of Mines, and on the Federal Council for Pure and Applied Chemistry.

Grants to Other Associations.—During the year the third and last yearly instalment on account of the £500 voted by the Council in 1917 as a grant was paid to the British Engineering Standards Association (Engineering Standards Committee), for the purpose of assisting that Association to increase its activities abroad. The sum of £50 was also subscribed to the funds of the Conjoint Board of Scientific Societies for general purposes.

Changes on the Council.—At the Council meeting on November 20, 1919, Dr. J. E. Stead, F.R.S., Vice-President, was unanimously nominated by the Council to succeed Mr. Eugene Schneider as President of the Institute at the annual meeting in May, 1920. The Vice-Presidents and Members of Council who, in accordance with Bye-Law 10 of the Institute, were announced at the autumn meeting, 1919, as being due to retire in rotation at the annual meeting in 1920, were: *Vice-Presidents*—Mr. W. H. Hewlett, Mr. C. J. Bagley, and Sir W. H. Ellis, G.B.E. *Members of Council*—Professor Henry Louis, Lord Airedale, Mr. W. Peter Rylands, Mr. Frederick Mills, and Professor H. Le Chatelier. The two vacancies in the list of Vice-Presidents, consequent on the election of Dr. J. E. Stead as President and on the death of Mr. George Ainsworth, have been filled by the election of Mr. M. Mannaberg and Lord Airedale as Vice-Presidents. The two vacancies which have thus occurred on the Council, together with the vacancy due to the resignation of the Marquess of Graham, have been filled by the election of Mr. H. Brearley, Mr. F. W. Gilbertson, and Mr. George Hatton as Members of Council.

In view of these changes, the list of Members of Council who, in accordance with the foregoing Bye-Law, are due to retire in May, has become as follows:—Professor Henry Louis, Mr. F. W. Gilbertson, Mr. W. Peter Rylands, Mr. Frederick Mills, and Professor H. Le Chatelier. No other members having been nominated up to within one month previous to the present annual meeting, the retiring members are presented for re-election.

ACCOUNTS.

Mr. Illtyd Williams (Honorary Treasurer), in presenting the Statement of Accounts for 1919, said it would be remembered that the Council recently issued an appeal to members voluntarily to increase the amount of their subscriptions for the year 1920 by paying an extra amount of £2 2s. each. The result of that to date was that the sum of £1,390 had been voluntarily paid, and on behalf of the Council he tendered sincere thanks to those members who had seen their way to help in that direction, and he would urge those members who had not so contributed to give their most kindly consideration to the appeal. The necessary steps to increase the amount of the subscriptions had been sanctioned by the Council, and, in compliance with the Rules, formal notice would be given at the autumn meeting of the resolution which must be submitted at the annual meeting a year hence.

The Report of Council and the Statement of Accounts were adopted unanimously.

INDUCTION OF NEW PRESIDENT.

The Retiring President (Mr. Eugene Schneider), in inducting into the chair the President-Elect, Dr. J. E. Stead, F.R.S., said that Dr. Stead's election to the Presidency of the Institute clearly showed the progress made by the idea that he personally advocated two years ago of co-operation between the metallurgical industry and the scientific mind. He was particularly proud of having as a successor an eminent scientist, for Dr. Stead had long enjoyed a world-wide authority in metallurgical science. At the close of his term of office, he would like to say once more that in the honour conferred upon him in being invited to occupy the Presidential Chair he had seen a gracious compliment paid to the French nation and to the industry of France, and he thought he was not mistaken in stating that the members meant to proclaim thereby how enduring must be the bonds of fellowship forged by the war.

The Chair was vacated by Mr. Eugene Schneider, and taken amid hearty cheering by Dr. J. E. Stead, who replied in feeling terms to the eulogistic remarks Mr. Schneider had made.

Sir Robert Hadfield, on behalf of the members, moved a vote of grateful thanks to Mr. Schneider for the great work he had done on behalf of the Institute during his term of office as President. Mr. Schneider had always shown special sympathy towards the English nation, and that had been strikingly evidenced by his generosity on a recent occasion. Although everyone was inundated with calls on his money at the present time, he (the speaker) took the opportunity of placing before Mr. Schneider the appeal for funds for the Engineering College of the University, and Mr. Schneider at once responded with a handsome gift of £200. Mr. Schneider therefore showed not only in words but in deeds his great sympathy with an Allied nation.

Dr. Arthur Cooper seconded the motion, and it was carried with acclamation.

Mr. Eugene Schneider, in reply, said he very much appreciated two years ago the honour which was bestowed upon him when he was elected President of the Institute, but he had always appreciated that that election was an emblem of the friendly and kindly co-operation which existed between the two countries.

BESSEMER GOLD MEDAL.

The President, before presenting Mr. Harry Brearley with the Bessemer Gold Medal for 1920, entered upon a review of the recipient's career, and described how he "won his spurs" in Russia as chief of the metallurgical department in Firth's armament factory in that country, subsequently becoming general manager of the works. Later he returned to Sheffield and established the Brown-Firth Research Laboratory, where he made the greater number of his original researches. It was a great pleasure to him, on behalf of the Council, to present the Medal to Mr. Brearley and to welcome him into the fraternity of Bessemer Medallists.

Mr. Harry Brearley was then presented with the medal amid hearty cheering, and in thanking Dr. Stead and the members, said he was practically born to the steel trade, and he cherished impressions and recollections of melting furnaces that were obtained before he went to school or during very early school days. He paid a high tribute to his brother, and said that since 1882, when they made toy furnaces together in the cellars at Thomas Firth & Sons, they had never been separated. All the opportunities that had been afforded to one brother had always been shared by the other, and if it were possible to cut the Medal in two he would give his brother half of it. They had had thousands of discussions together about steel and steel making, and had always tried to crystallise their differences into some question which could be the subject of an experiment; and the making of those experiments during the last 20 or 30 years had been one of the most interesting features in both their lives. No man ever had a better colleague, a severer critic, or a kindlier friend, and in thanking the members of the Institute for the Medal he wished to acknowledge that much of the merit of the work he had done belonged to other people. That dependence on the willing help of others was especially true of the individual who successfully directed a laboratory for industrial research purposes. To deal with a problem which could be stated was comparatively easy, but most problems relating to iron and steel making could not be completely stated. The individual who was best qualified by experience to study the problem

and go some way towards solving it was very often some crude workman who was engaged on the job day after day. Those men had a habit of expressing themselves in a kind of verbal shorthand, which was easily understood by those people who were familiar with it, but it took a great deal of understanding. He deliberately said that the investigator's greatest achievement was to inspire interest in such men, and make them confederates to his plans. The lust to work, the desire to find out and to understand, was not confined to those men who regularly wore clean collars, and in thanking the members for the very great honour which had been done to him he wished to confess his life-long indebtedness to scores of friends who had got hard hands and black faces and who sweated regularly in mills and forges.

AWARD OF THE GOLD MEDAL AND FREEDOM OF THE BLACKSMITHS' COMPANY.

THE PRESIDENT announced that Mr. W. H. Cathcart had been selected by the Council of the Institute to receive the gold medal and freedom of the Blacksmiths' Company from the Prime Warden and Wardens of the Worshipful Company of Blacksmiths. The reason was that Mr. Cathcart had formerly been a blacksmith, and had worked up his way to the foremost position. He was the first man to write a book for the benefit of blacksmiths, called "Science in the Smithy," and a very able book it was.

THE PRESIDENT then went on to deliver his inaugural address.

Presidential Address.

As it is fifty years since Dr. Stead first entered a metallurgical establishment to act in the capacity of analyst, this may be regarded as his Jubilee year, and hence it appeared to him that having been connected with metallurgy for half a century, a condensed review of the progress made during that period in the ferrous industries would be appropriate. The subjects dealt with in his address include:—(1) Blast furnace; (2) puddling process; (3) science in the foundry; (4) basic Bessemer and basic open-hearth processes; (5) electric furnace; (6) production of sound ingots; (7) recognition of science; (8) advent and progress of metallography; (9) application of science to the ferrous industries; (10) encouragement of research; (11) technical education. The following are a few abridged abstracts from the Address:—

Blast Furnaces.

The development in blast-furnace construction in England after 1870 was not very rapid. The chief advances consisted in working the furnaces at higher pressure and increasing the number and area of the tuyeres. The late T. C. Hutchinson, in May, 1918, proved the importance of having the furnace bell of such diameter that the fine ore would remain at the sides and the coarser material roll towards the centre of the furnace. By increasing the diameter of the bell from 13 ft. to 15 ft. 6 in. he effected a saving of 2 cwt. of coke per ton of iron—namely, from 24 cwt. to 22 cwt. He claimed also to have proved that the changed conditions prolonged the life of the furnace linings by throwing the small material against the walls of the furnace. The dimensions of the furnace are:—Height, 82 ft.; bosh, 23-26 ft.; hearth, 10 ft. The same authority indicated the great importance of cleaning the Cleveland ironstone by removing the sulphurous material and shale. The pig-iron, produced as a consequence of so cleaning the stone, contained only 0.035 per cent. sulphur on an average, the silicon being 2.8 per cent.

In America great advances in output began about 1876, and the make per furnace was much increased by the use of higher pressure and greater volume of air, while mechanical arrangements for charging the furnaces led in 1899 to an output of 2,462 tons per week per furnace. Within the last year or two, by increasing the diameter of the hearth from 15 ft. to 18 ft. and even more, 3,500 tons per week have been made, with a coincident saving of about 1 cwt. of coke per ton of pig-iron made. The system of providing separate blowing-engines for each furnace, and regulating the quantity of air by measurement instead of by pressure alone, contributed to this excellent result. The question is often asked why British makers do not adopt American blast-furnace methods. They have adopted many of them, such as the mechanical methods of charging, the use of bosh-cooling plates, and the mud-gun for closing the tapping-holes. They have also, in some works, adopted the method of providing a blowing-engine for each furnace, but have not considered it advisable to drive the furnaces making hematite pig-iron at so high a rate as in the American practice. They consider that excessive driving leads to the production of pig-iron low in silicon and to the speedy destruction of the furnace linings, also that the economic conditions are very different in the two countries. Here, the existing furnaces supplied all that was demanded of them when worked at a medium speed, and the profit of making pig-iron, for years before the war, was moderate; whilst in America, demand being almost always ahead of production, the profits of working were relatively high per ton of pig. But although English hematite users required that the pig-iron should contain between 2 and 3 per cent., or even more, of silicon, this does not apply to basic steel. Indeed, the lower the silicon can be kept in such iron compatibly with a coincidentally low proportion of sulphur, the better. This condition can be obtained by very rapid driving.

One great firm in the North of England, wishing to try the latest American methods, arranged with American engineers to build two furnaces of the latest and best type. The engineers were given carte blanche to do exactly as they wished. The plant was built and started in 1905, but while the output per furnace exceeded 2,000 tons per week when working Spanish ores, and reached 1,800 tons when smelting calcined Cleveland ironstone, the cost of production per ton was quite as high as when making pig in the best type of English furnace. The following are the dimensions of the furnaces:—Height, 100 ft.; bosh, 22 ft.; hearth, 13 ft.; number of tuyeres, 10; diameter of nozzle, 6 in.; pressure of blast, 12 lbs. per sq. in. The Americans also erected kilns for calcining raw Cleveland ironstone by blast-furnace gas, but after extended trial it was found that the cost of maintenance was great, and that as there was always a sufficiency of cheap coke breeze available it was more economical to use it instead of gas, the latter being much more valuable for other purposes. The experience with these furnaces and kilns has not induced English makers to duplicate them.

It is now most fully recognised that from every point of view it is imperative to clean all blast-furnace gas and to use the clean gases in stoves, boilers, etc. It is admitted that clean gas per unit of calorific value gives up more of that heat to a boiler and stove than gas loaded up with dust. In places where gas blowing-engines have been established in this country, the Theisen type of gas washing has been adopted for the fraction required by the engine itself; but it is now recognised that washing out the dust from the whole of the gases is not practicable owing to the enormous amount of water required, and the difficulty of disposing of the sludge, which, of course, cannot be allowed to pass into the water-ways. There is also the disadvantage that the potash salts in the dust cannot be recovered from the wash water. Dry cleaning is therefore necessary. Several methods of doing this have been proposed, and many blast-furnace proprietors are anxious to discover which method will best meet the conditions prevailing at their works. The Halberg-Beth system has found favour in works both on the Continent and at home. It is admitted, however, that the gas from this system requires further cleaning to remove the last portions of dust in order to make it suitable for use in gas-engines.

The cutting-off of the supplies of potash salts from foreign sources made it imperative for Britain to obtain

supplies from the fumes given off from cement kilns and blast furnaces at home.

The introduction of dry blast by the late James Gayley, as described by him in 1904, led to a reduction in coke consumed per ton of iron from 2,147 lbs. to 1,726 lbs., the saving being due, it was alleged, partly to uniformity in the blast itself and partly to other causes. A later trial recorded in 1905 led to a reduction of coke from about 2,248 lbs. to 1,815 lbs. Ehrenwerth, in 1913, when discussing the question of economy by the use of dry blast, concluded that provided the condition of the atmosphere as regards moisture is high enough, the adoption of dry blast is certain to be worth consideration. The question, now that the price of coke is so great, is whether in the altered conditions it would be advisable to reconsider the whole question, particularly in the application of dry blast in the manufacture of ferro-manganese, for if the coke could be reduced by 15 per cent., the air blown in would also be reduced and there would be a corresponding reduction in the amount of manganese volatilised.

The heat in a hundredweight of molten slag from a Cleveland blast furnace making No. 3 iron is 550 heat units. The slag thrown off per ton of pig-iron produced varies from 20 to 37 cwt., but the average from all furnaces, including those making hematite pig-iron, is probably near 30 cwt., which at 550 heat units equals 2.06 cwt. carbon, or 2.31 cwt. coke containing 89 per cent. carbon. Professor Bone's estimate for the heat in 35 cwt. Cleveland slag is 2.62 cwt. of coke. Messrs. Bell, at their Clarence Works, made experiments to recover the heat from slag. The heat recovered was estimated at about 40 per cent. of that in the slag. Owing to the war the experiments were abandoned, and the process is not in operation at the present time. The question is worthy of the most serious consideration by engineers. Even if only 33 per cent. of the heat were recovered from the fifteen million tons of slag produced in Great Britain alone, it would represent (at, say, 0.45 cwt. carbon per ton of slag) about 350,000 tons of carbon per annum.

Fifty years ago practically the whole of the coke used in blast furnaces was produced in the extravagantly wasteful beehive ovens. To-day the greater portion is produced in patent ovens from which valuable by-products are obtained. For many years it was believed that patent coke was inferior to the beehive, but to-day good patent coke is regarded as equal to the other for all purposes excepting the melting of crucible steel. Mr. Gerald Cochrane, of the Ormesby Ironworks, stated that his firm long ago tried beehive coke in one of their furnaces, and then patent coke made from the same coal, and found the latter to be even superior to the beehive; for as soon as the patent coke replaced the other the burden had to be increased, and the coke required per ton was reduced about half a cwt.

Soon after Pourcel had proved (in 1875) that rich ferro-manganese could be made in blast furnaces, English makers also produced it. The only requirements were rich manganese ores, coke and limestone.

In reviewing the past, and the evidence before us, we can draw the following conclusions:—

(1) There seems to be no advantage in having the capacity of the blast furnace above 30,000 cub. ft.

(2) The working of furnaces is best controlled by having a separate blowing-engine for each furnace.

(3) If increased output per furnace is desired, this can be attained by widening the diameter of the hearth and increasing the volume of air blown in.

(4) All the available gases should be conserved by the adoption of the double bell, or other similar system of charging the materials.

(5) Having secured all the gases, means should be used to obtain a maximum proportion of their calorific value by freeing the gases from dust, by most carefully controlling the proportion of air for their combustion, and avoiding excessive heat being lost in the escaping gases.

(6) The coke ovens should be close to the furnaces.

(7) The coke should be handled as little as possible after it leaves the coke ovens so as to avoid the production of fines, and should be sufficiently hard to resist crushing.

(8) As coke in fine condition tends to disorganise the regular working of the blast furnace, and reduces the output of pig, the "fines" should be sieved off and the consolidated material charged into the furnace.

(9) There is sufficient evidence to show that given efficient gas engines it is advisable to use them in preference to steam engines.

(10) It is highly desirable to study how to recover the heat carried out of the furnaces in the slag.

(11) Having obtained by all the available means the maximum saving in heat, and having much more gas and heat from the blast furnaces and coke ovens than is necessary for the requirements of the blast furnaces, it seems probable that in the case in which coke ovens, blast furnaces, and steelworks are grouped together, sufficient gas will be available to do all the heating at the steelworks without using any raw coal.

(12) Having cleaned the gases, and having by the use of common salt or otherwise obtained dry dust sufficiently high in potash to justify its extraction, the potash should be recovered.

(13) The question of using dry blast should, in view of the high price of fuel, be most carefully reconsidered, for, if anything like a saving of 15 per cent. coke can be effected by drying the air, it should pay to do it.

Science in the Foundry.

Many years ago, when lecturing on Science in the Foundry, on one occasion I astounded the foundrymen present by the statement that, until the foundry industries appreciated the fact that the services of a trained metallurgical chemist were at least as necessary as those of a time-keeper, there was no hope for them. To-day nearly every large foundry depends on the chemist for the synthetic control of the iron charged into the cupola, and the smaller establishments, where the output does not justify the establishment of a chemical laboratory, recognise the fact that it is necessary to know the composition of the various consignments of raw material delivered to them, and would indeed be thankful if the pig-iron manufacturers would supply them with analyses of all consignments. Few can conceive what prejudice existed a few years ago in the minds of those who controlled the mixing of metals in the iron foundries. These gentlemen did not realise that although the fractures of the pigs they used might be the same in different consignments from any single firm of pig-iron makers, the composition varied to a considerable extent, and that corresponding variations resulted in their castings. At one works where advice was given how to prepare synthetically suitable meltings from local irons to replace more expensive material imported from a distance, the foreman expressed the view that the expert was a most dangerous man. In more than one establishment it is beyond doubt that when an analyst was introduced and his advice taken, something was done to produce a bad result. Before real progress could be made the foremen had to be replaced by men less prejudiced.

That cast iron of almost any desired properties could be produced, given the necessary varieties of raw pig-irons, had been proved long ago, even in the early seventies, by one firm in this country which synthetically produced, and still produces, almost any kind of iron required, namely, white iron suitable for carburising in the manufacture of crucible steel; iron having all the properties of cold-blast iron; iron suitable for the manufacture of chilled rolls, malleable castings, etc; but this was only possible because, from the first, chemical assistance was employed. It is now generally admitted that the peculiar properties of every brand of iron are due to differences in composition.

Perhaps the greatest advance in foundry practice followed the researches of Professor Thomas Turner on the Influence of Silicon on Cast Iron. The astound-

ing practical evidence of Mr. Charles Wood, of Middlesbrough, subsequently proved that by melting together two classes of iron from the same blast-furnace, each of which was absolutely unfit to use by itself, a mixture was obtained which yielded high-class castings. The irons referred to were white iron and so-called "burnt" glazed iron, the former being deficient in silicon, the latter containing about 4 per cent. of that element. Each iron was brittle by itself, but the mixture was good and even better than average foundry castings made from Nos. 3 and 4 foundry Middlesbrough irons. The market value of each of these irons (white and glazed) was low, and it was usual to put them back into the blast-furnace in small doses, thus working them off with the better metal. The value of such high-silicon glazed iron since that time has been recognised, and is in great demand at works where large quantities of inferior scrap or hard irons have to be melted in the foundry.

Even sulphur—the element all makers of pig-iron endeavour to avoid—say from 0.1 to 0.15 per cent., is now considered essential in cylinder castings. White and mottled pigs, both almost invariably high in that element, are necessary in their manufacture. Although for a long time the actual amount of graphitic carbon in castings was not considered worthy of consideration, it is now recognised that both the amount and character of the graphite has a direct bearing on the mechanical properties of the finished castings. Professor Turner and others have drawn attention to these facts. As an instance of the embrittling effect of large graphitic plates or flakes, it is only necessary to refer to the fact that a No. 1 hematite casting with 3 per cent. silicon, 3 per cent. graphitic carbon, and 0.5 per cent. combined carbon has a tenacity of only 10 tons per square inch. Metal of a similar composition without the graphitic carbon has a tenacity after forging of about 60 tons per square inch. When sulphur pyrites are melted in the cupola with very open iron so as to give 0.15 per cent. of sulphur in the mixture, a closer-grained iron containing the graphitic carbon in fine plates may be obtained, which is stronger in consequence.

One great advance during the last twenty-five years was the production of castings by melting mixtures of steel scrap and blast-furnace metal in the cupola, for they were much superior in toughness and strength to those made from furnace metal alone.

The property of high percentages of silicon in cast iron, in enabling it to resist corrosion by acids, has led to the extensive use of evaporating pans and other vessels in chemical works made from cast-iron alloys containing 10 per cent. or more of silicon.

To the science of the foundry a large number of well-known authorities both in America and Europe have contributed very important information.

Basic Open-Hearth Process.

Messrs. Bell Bros. worked their chrome-lined open-hearth furnaces at their Clarence works for only two years, after which they were dismantled, and in 1898 new furnaces were erected and worked under the control of Messrs. Dorman, Long & Company. From the first, instead of cold pig, liquid iron direct from the blast furnaces was used; no special quality of iron was made, but, as there were many blast furnaces from which to draw the metal, only that low in silicon and rather high in sulphur, such as foundry 4 or forge irons, was selected. Saniter, having by his desulphurising process at Wigan made it possible to deal with metal high in sulphur, was engaged to apply his process at the Clarence installation. The results were perfectly successful, and it was proved for the first time that ordinary Cleveland iron of forge quality low in manganese and rather high in sulphur could be readily made into perfectly good steel. An active mixer was afterwards introduced, and the silicon in the metal was reduced from about 2.2 to 1.2 per cent. From that time the works were extended to the present day and steel of the highest quality produced. After the success at Clarence, the open-hearth furnaces making steel from hematite pig at the Britannia Works of Messrs. Dorman, Long & Company were changed to the basic process, and were worked on the same lines as those at Clarence, with equally successful results.

In 1919 a completely new steelworks was started at Redcar by Messrs. Dorman, Long & Company, in connection with the Redcar and Coatham blast furnaces. The plant is quite up-to-date and consists of a 400-ton mixer and nine 70-ton open-hearth furnaces—five of which are working and four are in course of erection. Each furnace yields about 800 tons per week. The waste heat from the furnace gases is partially recovered by passing into boilers of special construction. The quantity of coal used per ton of ingots for the mixer is 1¼ cwt. and for the steel furnaces 5 cwt., including that used for heating up.

The following particulars of the details of working a modern steel-making furnace by the ore and molten pig process at the Clarence Works have been furnished by Messrs. Dorman, Long & Company, and are typical of what is done at each of their works. Into a fixed furnace of 50-ton capacity are charged:—Gellivare ore, 10 tons 0 cwt.; limestone, 7 tons 2 cwt.; cold pig-iron, 4 tons 12 cwt. After the materials are beginning to melt, 46 tons 6 cwt. of molten metal from a mixer are poured into the furnace. The metal percolating between the partially-fused ore and lime has a large surface exposed to the refining material, and desiliconisation and dephosphorisation are rapidly effected. After a time the cinder, more or less saturated with silica and phosphoric acid, froths and boils, and is allowed to escape from the furnace by special outlets. When the materials are quite fluid and the frothing subsides, samples are taken and analysed, and based on the result of this analysis the requisite amount of lime and oxides are charged into the furnace; at intervals samples are taken of both metal and slag, which are analysed. Guided by these, more lime or oxide, or both, are charged, and 5 cwt. of fluorspar. The sulphur and phosphorus can be reduced below 0.04 per cent., at the expense of lime, iron ore, and fluorspar. It is interesting to note that this—the process now generally used—is almost exactly that developed by the late J. H. Darby.

Messrs. Bolckow, Vaughan & Company, at their Eston Steelworks, have for some time discontinued the use of the Bessemer process and have made great extensions of their basic open-hearth plant.

Although it is not usual in this country to have fixed basic open-hearth furnaces of more than 50 or 75 tons capacity, the Phœnix Iron Company in the United States have introduced furnaces of 100 to 200 tons capacity, and to deal with these employ two ladles to receive the charge. It is reported that the larger furnaces are quite as easy to control as those of smaller dimensions, and that by their use decided economy as regards cost of production results. At the same works the sides of the open-hearth furnaces are built with a lining called metalkase, the bricks consisting of cases of soft iron tubes containing magnesite composition. Several furnaces in this country have been lined in the same way and are also reported to have given satisfaction.

Electric Furnaces.

Previous to the war only a few electric furnaces were used in connection with the iron and steel industry in Great Britain, but soon after 1914 a large number of melting furnaces—mainly of the Héroult type—were erected in Sheffield and other parts of the country to deal with the enormous mass of shell borings produced in every part of the country. They have been used largely to replace crucible melting and have come to stay. Immense quantities of special alloy steels were made by their aid, and since the war, in one works at least, the greater part of crucible steel has been replaced by electric steel.

The electric steel furnace, which, up to the outbreak of war, only produced a very small proportion even of the higher grades of steel, has developed with great

rapidity during the last five years. Before the war progress had been most rapid in Germany, where conditions were peculiarly suitable for its use. Most of the German electric steel was made by refining basic Bessemer steel, and furnaces up to 30 tons capacity have been installed for this purpose. The United States came second, and Italy, America, and France were all ahead of England in production. During the war, however, great progress was made here, and the production is now only surpassed by the United States and Germany. The latter still holds second place, but only because most of the steel there is refined basic Bessemer steel, while the British furnaces are in practically all cases melting cold scrap. The actual number of furnaces and the power used is greater than in Germany.

The output in England before the war was probably

MR. HARRY BREARLEY
(*Bessemer Gold Medallist.*)

MR. HARRY BREARLEY was born in 1871 in Sheffield, and attended the Board School between the age of 6 and 10 years. He then did odd jobs in a foundry and a clog factory, and as page boy, before starting on steel-making plant at the age of 12. He studied chemistry at the analyst's bench. Subsequently he became a metallurgist in Russia for four years, and has now been consulting metallurgist in private and public capacities for twenty years. He was works manager at Brown Bayley's Steel Works during the war and is now technical director of this and other companies. Mr. Brearley is the discoverer of "Stainless" steel and an inventor of other minor materials and apparatus. He is the author of books on analytical chemistry, the heat treatment of tool steel and on ingot making.

about 10,000 tons a year, though no exact figures are available. This was made in eleven furnaces with a total transformer capacity of about 4,500 kw. By the end of 1918 the number of furnaces of all types had increased to about 140, with a production of about 150,000 tons a year and a transformer capacity of nearly 100,000 k.v.a. The possible production at the present day, if all furnaces were worked to their full capacity, is about 300,000 tons a year. In 1918 a number of furnaces had either just started work or were not completed, and several were shut down immediately after the Armistice was signed.

The 1919 figures are not yet available, but the production was probably less than in 1918. In 1918 about 40,000 tons of the steel produced was required for the manufacture of castings. The problem of finding an immediate market for the steel from the furnaces making ingots, of which over 100,000 tons were produced in 1918, was a difficult one. During the war they were principally making steel for bullet-proof plates, aeroplanes, motor-cars, armour-piercing shell and steel helmets. On the Tyne electric steel is being made at a price which can compete with the acid open-hearth, cheap power being available from coke-oven gas.

In America and Germany electrically refined Bessemer steel is largely produced, and it is probable that a duplex process will be the next large development here. An electric furnace refining basic open-hearth steel made from Cleveland ore could produce steel of the quality at present made in acid open-hearth furnaces at a cost which would show a substantial profit at present prices.

Many years ago Dr. Stead had occasion to compare electric tool steel made in Sweden by the Kjellin induction furnace against the best corresponding quality of English crucible steel, and found that their cutting efficiency in the lathe was equal.

One of the latest advances in connection with electric steel is to melt it in an induction furnace in vacuo. Mr. Albert Hiorth, of Christiania, has designed a furnace particularly adapted to effect this object. The steel, after being melted in vacuo in the ring furnace, is allowed to cool down without admission of air into the furnace. The steel is then removed and cut up into sections for forging. By this means steel free from honeycomb and gases is obtained. It is, however, probable that the process is likely to be applied only for very high qualities of steel.

Metallography.

The Address in this Section briefly outlined "the birth of metallography" and its subsequent development, including the work of the pioneers, Sorby and Arnold, Osmond and Le Chatelier, Howe and Sauveur. Both Osmond's allotropic theory and Sir W. Roberts-Austen's carbon theory are duly discussed, and in going over the arguments for and against the two theories in the light of more recent research, says Dr. Stead, one must conclude that although the minds of a host of earnest workers have been and are still devoted to the subject we do not yet know exactly why quenched steel is so intensely hard. All agree that without carbon such hardness cannot be obtained. One thing is certain, however; when scientists of high degree differ so fundamentally, quite a multitude of students and others begin to work in the field in order by research to arrive at the truth. Although they have not been rewarded by finding what they sought, they incidentally found many other things, adding greatly to our knowledge. This activity went far to placing metallography on its throne.

Sorbitic Steel.

Osmond, by the microscope, proved that the tough improved condition of steel produced by heat treatment was due to the presence of sorbite. He stated that it was probable that the present methods in the manufacture of rails, etc., would eventually appear primitive, and he hoped that "the greater quantity of pearlite in our steel would in future be replaced by sorbite." Richards and Stead attempted to produce sorbitic rails by spraying the upper surface of rail heads with water after they left the rolls, but the crude process of spraying was difficult to control, and occasionally cracks were produced on the rail heads. The process was therefore abandoned. Within recent years, however, Messrs. Sandberg, by substituting a blast of cold air for water spray, produced the desired carbon condition, and rails treated in that way have given exceedingly good service on railways and tramways. Treatment of a more drastic nature is being obtained by the same gentlemen by heating to above the critical points, Ac1, the tread of tram rails in the permanent way by the oxy-acetlyene blowpipe flame, and the chilling of the metal so heated is effected by jets of water immediately following the flame. A layer of about 3-16 in. is thus converted into martensite which merges gradually into the normal structure. The Sandberg sorbitic treatment has not been confined to the hardening of rails, but has been successfully applied to tyres also.

The inventors claim that, unlike the present system of oil-hardening and tempering, the Sandberg treatment can in no case make the steel brittle. It is immaterial whether the treatment starts a few degrees higher or

lower in temperature so long as the temperature at the start of the treatment is well above the higher point of the critical range. They believe that if railway engineers realised how reliable and efficient the method really is, they would certainly specify the Sandberg treatment generally.

On the motion of PROFESSOR HENRY LOUIS a hearty vote of thanks was accorded to Dr. Stead for his Address.

The Distribution of Phosphorus in Steel Between the Points AC1 and AC3.

BY J. H. WHITELEY (STOCKTON).

In one of the many interesting and important experiments made by Dr. Stead on the relations between carbon and phosphorus in steel, two bars of a carbonless alloy, containing 0.50 per cent. of phosphorus in homogeneous solid solution, were heated in charcoal for six hours at 960 deg. C. and finally one hour at 1,150 deg. C. One of the bars was then quenched in water and the other allowed to cool in the furnace. By means of cupric etching reagents, Dr. Stead found that, at a point where the carbon was about 0.20 per cent. in the quenched bar, phosphorus had diffused out of the parts into which the carbon had penetrated, and the phosphorus content of the ferrite areas surrounding these parts had increased as a consequence. The metal was thus no longer homogeneous with respect to its phosphorus content. When the slowly cooled specimen was similarly treated, copper was only deposited on the ferrite areas enclosing the pearlite, and Dr. Stead showed that these bordering ferrite areas, the phosphorus content of which had evidently been reduced, represented those parts occupied by the γ-iron in the heated steel. This experiment clearly proved, therefore, that at the high temperature employed two solid solutions were present, one containing the carbon and the other practically free from that element but richer in phosphorus. The distribution of the phosphorus in this manner is not confined merely to phosphoric material such as the above; the investigation here recorded shows that, at temperatures between the critical points Ac1 and Ac3, a similar distribution occurs in all hypoeutectoid plain carbon steels if the critical range is approached from a lower temperature.

The author summarises the results of his research as follows:—

(1) When ordinary hypoeutectoid steel is heated to, and maintained at temperatures between the critical points Ac1 and Ac3, part of the phosphorus contained in the γ-iron diffuses into the adjacent ferrite owing to the fact that, under these conditions, the phosphorus is more soluble in the latter than in the former. With a series of steels in which the phosphorus varied from 0.006 to 0.12 per cent., evidence is obtained, in several ways, proving that it is phosphorus which diffuses out of the γ-iron and so gives rise to the etching effects obtained. The lowering of the solubility in the γ-iron is most probably due to the presence of dissolved carbide.

(2) At temperatures below 650 deg. C., phosphorus diffuses extremely slowly in ferrite; above this temperature the velocity gradually increases, and above 800 deg. C. it is quite rapid, for a diffusion which requires four hours to complete at 740 deg. C. is complete in fifteen minutes at 830 deg. C.

(3) The velocity of diffusion of phosphorus in γ-iron also increases with the temperature in a similar manner, but it is never so high as that at which the carbon travels. At or near the Ac^3 point the speed of diffusion suddenly diminishes.

(4) By heating steels slowly through the critical range, a cellular structure is produced which appears to be also due to the movement of phosphorus in the γ-iron The lowest temperature at which this structure is formed depends upon the carbon content of the steel; with 0 18 per cent. of carbon it was about 820 deg. C and with 0 06 per cent. 870 deg C.

(5) Owing to the fairly rapid rate at which phosphorus diffuses in γ-iron above 820 deg. C., it is possible, by heating sections of steel plates at a temperature just below the Ac^3 point, to remove completely the excess of phosphorus contained in the micro-ghost-lines included in the areas occupied by the γ-iron. This treatment does not entirely remove the lines, however. Their presence would appear to be due to the uneven distribution of some other substance besides phosphorus.

Some Defects in Electro-Deposited Iron.

By W. E. HUGHES, B.A. (Trin. Coll., Camb.), late Chief Research Chemist, Electro-Metallurgical Committee, Ministry of Munitions, and formerly Examiner in Electro-Metallurgy, City and Guilds of London Institute.

(*Summary*).

As the title of this Paper imports, it is intended to bring to notice some only of the defects that may, and frequently do, occur in electro-deposited iron. They are nearly all of them common to iron and other metals; and most of them are well known in a general way. The particular object of the Paper is to show the effect of them upon the structure of deposited iron. Microscopic and macroscopic examination shows that electro-deposited iron is subject to the following defects:—(1) Pin-holes; (2) lumps (or roughness)—these (1 and 2) may be classed (with others) as surface defects, though they affect the internal structure as well—(3) inclusions (of foreign matter); (4) cracks and quasi-cracks; (5) differences of structure—at different parts of the same specimen.

The author's conclusions from the experiments and observations—so far as they have been at present taken—are:—

(1) That electrolytic iron is liable to suffer from a number of defects that may render its use dangerous, and make it unsuitable for engineering purposes without separate heat-treatment.

(2) That these defects arise from causes which can be largely eliminated by efficient control and conduct of the deposition process.

(3) That electrolytic iron is often far from being the pure product it is usually considered to be, and, consequently, cannot be taken as pure for the starting point of research work.

(4) That electrolytic iron is not necessarily hard or brittle. It is usually assumed to be hard. It may indeed be so. Whether the hardness, where it occurs, is due in fact to included hydrogen requires to be positively established. The present investigation has not been taken far enough to justify a definite opinion, but it has proceeded so far that it can be definitely said that the often expressed opinion that hardness is due to included hydrogen is subject to question.

The author points out in conclusion that several of the statements made above might be construed as implying that electrolytic iron is useless for several of the purposes to which it has been put—especially of late—as, for example, in the "building up" of worn parts of guns and aeroplanes. Any such construction would be erroneous. On the contrary, it is believed that electro-deposited iron could be used with advantage to a much greater extent than it is at the present time, and that a great saving of material and expense would be effected by such extended employment of it. But the author is sure from long experience that if the electro-deposition process is to be used with success this will have to be done by methods and under workshop and other conditions that are much less lackadaisical and much more scientific than those at present practised.

Practical Notes on the Design and Treatment of Steel Castings.

By George F. Preston (Sheffield).

(Abridged.)

Steel castings are used extensively for very diverse purposes. Some difficulties which have arisen in the foundry have been due to the non-appreciation of the fact that, at the recalescence point Ar3 in the cooling curve of steel, contraction is arrested and an actual expansion takes place. In an ordinary 0.3 per cent. carbon steel the expansion between 690 deg. and 650 deg. C. is approximately equal to the amount of contraction between 790 deg. and 710 deg. C.; therefore in some castings of intricate design reversals of stress do not occur simultaneously in all parts. If such castings are left in the sand or on the floor, cooling at

Fig. 1.

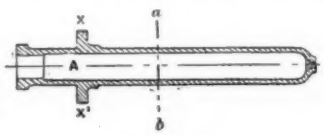


Fig. 2.

unequal rates in various parts, contraction will be taking place in some portions whilst in others expansion will occur, when adjacent members are in a plastic, or weak condition, resulting in "pulls" or "cracks." When such difficulties due to reversals of stress occur, modification in design by the engineer, so as more nearly to equalise the thicknesses in critical parts, affords one means of remedy. Another is by "chilling" or using one of the various methods, not altogether looked on with favour by the engineer, for making the thicker sections cool more rapidly where feasible, or, for any other reason, not undesirable.

Most steel-founders have probably experienced cases where the use of "chills" has been followed by "cracks" in the casting, through the effect of using

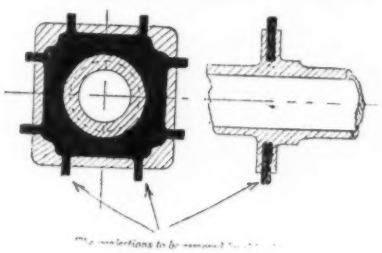


Fig. 3. — Section showing Method of Fixing suggested Chill, preheated before Casting Operation.

such chills not having been fully considered. An alternative method which might be adopted for some castings is to arrange for the cooling from a temperature above 770 deg. C. to take place in a preheated furnace, care being taken to "strip" the casting at a temperature sufficiently above this to enable it to be sealed up in the furnace before the temperature has fallen to the danger point.

Cases occur where the engineer would be put to increased cost, or experience a difficulty, by omitting some portion objected to from the founder's standpoint, as, for example, in a cylinder or tube such as that shown in Figs. 1 and 2, having a heavy flange, XX^1, 2 to 4 ft. from the mouth, and used only for bolting the cylinder on to its entablature, which present two difficulties to makers. One is to feed the square flange to ensure soundness; the other, which is possibly of more consequence, is to prevent pulling in the bore of the cylinder about the centre of the width of the flange (see "A"). In such cases probably no really serious objection could be raised to introducing in this heavy flange a frame (Fig. 3), previously cast in steel, to act as a "chill," thus equalising the rate of cooling and also insuring an absence of cavities in the surrounding metal. There would be little theoretical and probably no practical loss of strength, as unless the "chill" was of excessive thickness it would to a large degree be fused by the fluid steel.

In the case of important castings subjected to severe stresses, such as large gun mountings, etc., the fullest and most careful consideration should be given by the designer to the placing of heavy masses or sections of metal where adequate arrangements can be

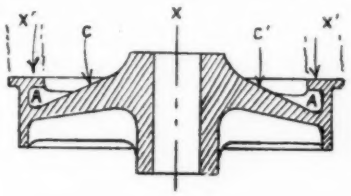


Fig. 4.

made for "feeding," as, in the absence of "feeding heads," the thinner surrounding sections will "draw" on such reservoirs of molten steel and result in unsoundness or "piping" in parts where it is of the utmost importance that a large factor of safety should be provided.

Castings of the type shown in Fig. 4 are sometimes asked for, with light ribs, AA, tied under internal flanges and also to a heavy plate or cone centre, CC^1. Such ribs naturally cool at a much quicker rate than the heavy disc portion and "feeding heads," XX^1, and are therefore in considerable tension, where the members join the periphery, when the plate portion and the centre boss have reached their maximum contraction.

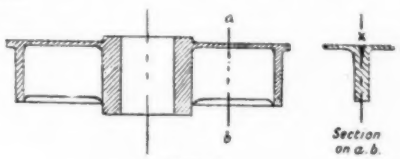


Fig. 5.

It is likewise a difficult matter to ensure perfectly satisfactory castings of such design as shown in Fig. 5. This shows a disc, or wheel, having spokes of heavy rectangular section on which are superimposed a plate of lighter section. "Drawing," or other defects, will probably appear in the plate over the centre of the spoke or rib (see X on section *a b*).

It must be admitted that a careful consideration by the management (and especially a joint discussion with all foremen responsible for seeing work through the different shops) of the problems to be faced in these and similar instances would conduce to the production of better castings; as it is sometimes seen, after a pattern is completed, that, if it had been made differently in some respect, to allow of a modification in the method of making the mould, provision could have been more efficiently made for "feeding," and also for guarding against contraction and other troubles.

Such expedients as the insertion of tubing of small diameter and of considerable length rammed with sand, in lieu of cores where they are surrounded by

large masses of steel—which cores would necessarily have to be made hard to stand and would become much more so through the contraction of the steel—would probably then be arranged for and much expense be saved in fettling and in the machine shop. It is well known that bent or broken cores cause endless trouble when the casting reaches the drilling machine; in fact, in many instances it would be far cheaper to omit small bolt-hole cores altogether.

There is also a danger of small cores in one plane (say for a number of bolt-holes) causing vital cracks in large castings of heavy section, owing to contraction, the cores becoming very hard and offering great resistance whilst the steel is semi-plastic.

Steel-founders of repute have overcome the trouble of "honey-combing" and blowholes in castings.

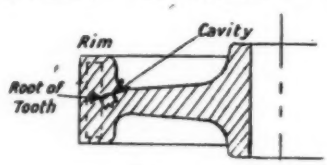


FIG. 6.

These in earlier days were considered almost unavoidable, in fact it has been stated in the past that the presence of blowholes might be taken as a "guarantee of quality in other respects"! Given steel properly melted and with suitable percentages of silicon and manganese, and care in making and drying moulds, little trouble is experienced in this respect; "piping," sand defects, etc., being far more frequently the cause of wasters.

The elimination of "honeycombing" has resulted in very largely increased productions of cast steel blanks for machine-cut gearing and similar castings, on which a large amount of machining is done; but, owing to the serious loss which would be incurred if defects developed, particularly at a late stage in the machining operation, it is very necessary that everything which can possibly be done to ensure perfection

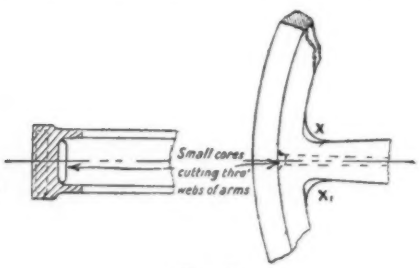


FIG 7.

should be given earnest consideration. Arrangements should be made for the fluid steel to enter the mould at the bottom, and whenever possible a centripetal action, commonly termed "spinning," should be secured. Suitable risers and "feeders" should be provided where necessary, to ensure any "dirt" being brought up into the "heads." It is usually advisable to cast such articles quickly.

Castings of this kind are frequently produced without the slightest defect, provided the design be favourable. One cause of trouble has been due to the founder being asked to supply blanks of fairly large diameter with solid disc, or plate, centres (see Fig. 6), which have a pronounced tendency, in large diameters, to result in cavities being formed in the rim, practically in the position where the roots of the teeth are when these are "milled" out. This is due to the rim being of heavier section than the disc and therefore remaining fluid longer, and also, in cases where the change in section is not so great, to difficulty in arranging for adequate "feeding" at this place.

It is preferable to adopt "H" section arms (see Fig. 7), but it is then found expedient to break the continuity of the metal at the junction with the rim by placing a narrow core through the webs of the arms. If objection be made to such a method resulting in any weakening of the casting, this can easily be obviated by increasing the strength of the faces, or top and bottom flanges, of the arms by having larger radii between them and the rim (see XX¹), which is preferable from the founder's standpoint as well.

The same problems are encountered in the production of smaller castings, weighing from a few ounces upwards, as supplied to motor and general engineering firms. The difficulties might be overcome in many instances if it were possible to arrange to submit suggested designs to some steel-founder of good standing beforehand.

It is not intended, however, to convey the impression that all faults lie with the drawing-office, as by careful attention and thought on the part of the foundry staff better articles could be produced by judicious use of chills, "feeders," etc. Further interchange of opinion would, however, undoubtedly lead to increased efficiency and obviate some of the troubles experienced by the engineer.

To give one example only: Axle-box guides for locomotives, etc., are still made as shown in Fig. 8.

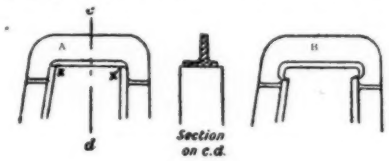


FIG. 8.

A, which any user will understand generally results in "drawing" at X and X¹, in addition to causing extra work in the machine shop owing to the absence of tool clearances, instead of a more gradual change in section and also of radii at the corners, as illustrated by Fig. 8, B, the more usual present design.

Innumerable examples might be adduced (hydraulic cylinders having square instead of rounded or spherical ends, for instance) affecting practically every type of steel casting made, but the desire at the moment is to persuade the engineer that exchange of views is of importance not only in respect of the production of castings without inherent weaknesses, but also in regard to the use of differing qualities of steel, or of special alloy steels, for various purposes.

The provision of suitable test-bars, in the case of some forms of castings, is an important matter if sound pieces for tensile and bend tests are to be ensured. This should not be left to the discretion of the moulder, who is usually—in deciding where to place these—governed by considerations of convenience in respect to the moulding box used for the job. The question is well worth consideration by the management, owing to the loss incurred if a satisfactory casting be rejected solely through inability to obtain test-pieces free from defects. In some cases, on cutting up a casting for test to represent others produced from the same cast of steel, or on breaking it under the tup for remelting, it has been found that the casting was perfectly sound, defects appearing in the test-pieces only.

It is also highly advisable to provide for spare test-pieces, as cutting pieces from "rising heads," etc., often results in disappointment from causes such as segregation, etc.

Consideration should be given to such points as "feeding" the test-bars, and whether the steel is

able to flow freely through the part provided for tests; whether any dirt carried off the face of the mould, etc., may be trapped, and whether the test-bar will be sound at the expense of unsoundness in the casting itself or *vice versâ*.

For small castings it is advisable to treat the test-bar as a separate casting, but connected by a "spray" of sufficiently large sectional area to ensure that the test-piece is securely attached to the group of castings, or to the single casting, as the case may be, and also to give an adequate flow of steel into the test-bar, on which a separate feeding head should be superimposed. A suitable design of test-piece for this purpose is shown in Fig. 9.

The provision of test-pieces from small castings may add very considerably to the cost of production, especially in cases where only a few are required from a pattern. This should be borne in mind when quoting, and the most favourable arrangements made with the inspecting engineer, as to including a quantity from one cast of steel as well as from a single moulding box.

When moulds are made by machines, it will be found convenient to arrange the patterns on the plate, whenever possible, so that one or more patterns can easily be removed and a test-bar included in place in several of the moulds which will be put down for each cast. Special attention must necessarily be given to the method of fastening patterns to the plate to prevent any possible chance of displacement through the more frequent changing.

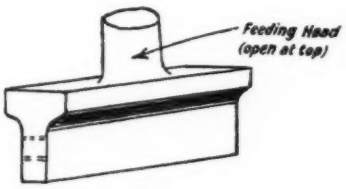


FIG. 9.

To ensure satisfactory test results, it is necessary that the annealing or rather "heat treatment" (as the great majority of castings are now cast in mild steel and "annealing," *i.e.*, softening, to permit of the castings being readily machined, was principally required for crucible steel castings), should be carefully carried out. It is very advisable to have some means of recording temperatures, readings being taken in various positions in larger furnaces; at any rate until it is ascertained that something approaching a uniform heat is obtained in the particular type of furnace in use. The furnace attendant, if left to himself, often appears specially interested in recording flame temperatures rather than those of the castings under treatment. If personal attention is given, by someone holding a responsible position, to this matter of heat treatment, economies in working, as well as higher quality material, etc., may result, as small modifications in furnace design, for instance slight alterations in the sizes and positions of admission ports, may be found advantageous.

There is no doubt that an experienced workman can judge temperatures to within a reasonable variation, at any rate under the atmospherical conditions he is accustomed to, but it will usually be found that the tendency is to estimate the temperature higher at night than in daylight, and the cost of a pyrometer is money well spent.

The most satisfactory furnace is one in which the rate of cooling down at the critical temperature can be varied to some extent, as it is then possible to obtain small variations in the maximum stress where castings are made to stringent specifications.

Owing to the difficulty sometimes experienced in obtaining permission for material—which has given results say 2 to 3 tons over, or under, the maximum stress specified—to be retreated, it would appear that some engineers have not yet realised that the rate of cooling round the recalescence point of the steel governs the maximum stress, and that a substantial increase, or decrease, can be made by accelerating or lengthening the period of cooling through this range.

It is found in practice that heating to a temperature of about 950 deg. C. is advisable to ensure the "breaking down" of the cast crystalline structure, the final structure being, of course, coarser or finer according as the rate of cooling through the critical range is slow or rapid. This temperature is much higher than is theoretically necessary, but experiments over a considerable period show the necessity for the higher temperature. The original crystallisation of a casting will, of course, be governed by the mass of metal and the rate of cooling after casting either in the mould or, if "knocked out," early after casting, on the foundry floor.

The length of time necessary thoroughly to "soak" castings and complete the "breaking down" throughout is a matter of judgment depending on size, thickness of metal, position the castings are loaded in the furnace, and probably several other considerations.

When dealing with large castings of heavy section it is advisable to pack them well up from the floor of the furnace. If this can possibly be done, pieces having heavy cores should be rough fettled before being placed in the furnace. The annealing will then be more efficiently and expeditiously carried out.

Generally, if arrangements are made which will admit of castings being cooled off quickly through the critical range without risk of distortion, setting up of stresses, etc., through currents of cold air impinging on one part of a casting, or other causes, an increase in the maximum stress without decrease in the elongation can be looked for and, owing to the closer structure, better results from bend and shock tests obtained.

Many cases have been noted where mild qualities of steel, as cast, have given practically the same maximum stress and elongation per cent, as after annealing, for instance a breaking strain of about 30 tons per sq. in. with 28 to 30 per cent. elongation in 2 in. Untreated samples fail, however, to give anything approaching satisfactory bend tests.

It is possible that manufacturers of high-quality castings may soon consider that some form of shock test might, by no means, be against their interests if lower-grade material, less suitable for the purpose required, and supplied at a cheaper rate, be in this way eliminated from competition.

The aim of every maker should be to produce castings absolutely, not commercially, free from defects, and the engineer should be willing to give earnest consideration to any reasonable modifications which may be suggested by men of experience. By close co-operation, steel castings might be produced which could be used with the same confidence as is extended to forgings when it is borne in mind that practically the same structure in the steel can be obtained by correct heat treatment as by work done on the steel during the process of manufacture.

NEW BLAST FURNACE AT NATAL, AUSTRALIA.—A new blast furnace is being erected at Natal, Newcastle, Australia. It is to be 14 ft. × 65 ft. on eight columns, with seven tuyeres. The hearth level is 9 ft. above the veldt, and the ground slopes down to the pig beds at a gradient of 1 in 100 ft. The foundation, 9 ft. deep, rests on solid sandstone. The iron ore to be used is mostly magnetic, and very rich, running between 60 and 65 per cent. metallic iron. It is at first intended to manufacture cast-iron pipe, and the management is in negotiation for machines working on the centrifugal principle.

The Properties of Cast Iron.*

By A. C. Timmins (Barrow-in-Furness).

When pig-iron is melted under oxidising conditions to decrease or even to remove certain constituents, as, for instance, silicon, it is known as refined iron. In certain cases the purification or oxidising action is carried so far and under such conditions as to remove nearly all the silicon, manganese, phosphorus and sulphur, leaving only the carbon in the combined state, and this product is now known as washed metal.

A few analyses of brands which can easily be obtained are as follows :—

Refined Hematite (Barrow Hematite Steel Co.).

	White.	Mottled.	Grey, No. 6.
G.C.	Nil.	1.35	1.60
C.C.	3.65	2.30	2.10
Si.	0.55	1.00	1.25
S.	0.225	0.15-20	0.18
P.	0.055	0.05	0.05
Mn.	0.16	0.18	0.20

Cast only in small pigs, without sows.

Refined Hematite.

	White.	Mottled.	Grey, No. 6.
G.C.	Nil.	1.35	1.60
C.C.	3.65	2.30	2.10
Si.	0.55	1.0	1.25
S.	0.225	0.15 to 0.20	0.18
P.	0.055	0.05	0.05
Mn.	0.16	0.18	0.20

This is cast in small pigs only, without sows.

No. 1. Hematite (Foundry).

Silicon	2.85	This iron can be given with Si. as low as 1.75 and up to 4½ per cent. S. is lower in the higher Si. iron, with a reduction in Mn. and a slight rise in the P.
Sulphur	0.035	
Phosphorus ..	0.048	
Manganese	0.75	
Carbon (G.) ..	3.85	
Carbon (C.) ..	0.10	

Hard Irons.

	White.	Mottled.	No. 6.
G.C.	Nil.	0.75	1.50
C.C.	3.75	3.00	3.25
Si.	0.60	0.85	1.10
S.	0.30	0.25	0.185
P.	0.055	0.055	0.055
Mn.	0.150	0.160	0.175

This iron is cast in three sizes : medium, medium, and small pigs.

White Facing Sand.

Silica	81.55
Al_2O_3.	6.00 to 6.40
Fe_2O_3.	1.50 to 2.10
Lime	0.14
Magnesia	0.45
Loss on Ig.	2.00
Moisture	7.14

The constitution of cast iron has not received the same attention from metallurgists as steel. Perhaps on account of the wide differences which occur in its five chief constituents, carbon, silicon, phosphorus, sulphur and manganese, it presents a more complicated problem than steel. How do we get these so-called impurities into the pig-iron? As soon as the iron ore, etc., enters the top of the furnace the reaction produces both metallic iron and carbon in a form similar to that of lamp-black, on the outside and in the interstices of the ore. There is always a large amount of silica present in the coke ash, and some of this is reduced according to the reaction $SiO_2 + 2C = Si + 2CO$. The extent of this reaction will depend on the length of time the iron takes to drop through the smelting zone, the relative intensity of the reducing influence, and the avidity with which the slag takes up silica. A slag with a high melting-point will trickle sluggishly through the smelting zone and cause the iron to do the same, to some extent, thus giving it more chance to take up silicon. A higher temperature in the smelting zone, which increases disproportionately the avidity of carbon for oxygen, will promote the above reaction. We can produce this higher temperature by supplying hotter blast. A larger proportion of coke to the burden will further promote this reaction, because this not only increases the amount of the reducing agent, but also raises the temperature, and therefore the chemical activity of this agent. Thus the coke has both a physical and a chemical influence in increasing the intensity of the reduction in the smelting zone.

A basic slag, because of its avidity for silica, will oppose the above reaction. It is one of the principal means of making low-silicon pig-iron. This is in spite of the fact that the basic slags are sluggish, and therefore trickle slowly through the smelting zone, thus exposing the silica longer to reducing influence, and also increasing the temperature of the materials in this zone (1) by causing them to pass through it more slowly and absorb more heat, and (2) by reducing the level of the smelting zone nearer to the tuyers, which confines the intense temperature to the smaller area, or in other words diminishes the passage of heat upward.

Sulphur comes into the furnace chiefly in the coke. It is partly in the form of iron sulphide (FeS) and partly in the form of iron pyrites (FeS_2), which loses one atom of sulphur near the top of the stock and becomes FeS, which will dissolve in the iron unless converted to sulphide of calcium (CaS). This is brought about (according to Professor Howe) by the following reaction—$FeS + CaO + C = CaS + Fe + CO$.

CaS passes into the slag, and accounts for the odour of sulphur when the slag is running from the furnace. It is evident from the above reaction that intense reduction, which increases the silicon in the iron, has a contrary effect on the sulphur, and this explains the quite common observation that iron high in silicon is liable to be low in sulphur.

Manganese is reduced by the following reaction—$MnO_2 + 2C = Mn + 2CO$. The amount of manganese in the iron is largely dependent upon the character of the ores charged, but it can be controlled somewhat by the character of slag made, because an acid slag will carry a large amount of

* Read before the Lancashire Branch of the Institution of British Foundrymen.

manganese away in the form of silicate of manganese ($MnO. SiO_2$).

The amount of phosphorus in the iron is controlled by the character of the ores charged, and districts or countries having high-phosphorus ores must have high-phosphorus iron. This is not an insuperable objection, because the presence of phosphorus in some irons is very valuable.

The advantages of cast iron, and which cause it to be used as much as it is, are its fluidity, lesser amount of shrinkage when cooling from the molten state, relative freedom from "checking" in cooling, and the ease with which very different properties are conferred upon it at will.

The disadvantages are its weakness and lack of ductility and malleability, which last-named deficiency renders it practically impossible to put any "work" upon cast iron. Its most important advantage is probably its ready fusibility, which makes it so easy to melt and cast; also its cheapness, compared with other material.

All the characteristic qualities of cast iron are due to the presence of the large amount of impurities. One of the largest and most important constituents is graphitic carbon. It occurs in thin flakes, in sizes varying from microscopic proportions to $\frac{1}{8}$ sq. in area, distributed through the body of the metal and forming an intimate mechanical mixture. Under the microscope each flake of graphite is composed of smaller flakes built up somewhat like sheets of mica, but with very little adhesion between the small component flakes, so that the sheet of graphite may be split apart with very little force. Those who deal with cast iron know that if the graphite is in large flakes the iron is weak. The graphite present should be in the finely divided form if the minimum tensile or transverse strength is to be obtained.

Some authorities regard all graphites alike, but others place importance upon the varieties of graphite. Moissan shows the higher the temperature at which graphite is formed the more refractory is it toward oxidising agents. These variations in carbon appear to open a very large field of investigation.

The shrinkage of cast iron is of great importance because the greater it is the greater will be the strains set up in the cooling of the casting, and consequently the liability to "check"; and there will have to be a greater allowance to make the casting true to size. Graphite is most important in this connection because of the expansion which its separation causes.

This separation should take place at the moment of solidification, but is usually not complete then, and therefore precipitation continues during the fall of the temperature several degrees below freezing point.

Grading by the silicon content of a pig-iron is undoubtedly an excellent guide to foundrymen, but owing to the great change in the methods of manufacture during the last quarter of a century, it does not furnish sufficient information when depth of chill and physical tests are required. Tests have been made and help to prove that pig-iron or cast iron has a physical condition independent of the chemical. This is more noticeable in blast-furnace practice, as it is perhaps remarkable how analyses differ fracture for fracture, and the facture analysis for analysis.

Two pigs can have apparently the same composition but different fractures, and when treated exactly in the same way may have different physical properties, from which the writer concludes that there are other elements, or their condition, which have not been revealed.

It has been stated that silicon turns carbon into its graphitic form; but, as a general rule, within the usual limits the rate of cooling being kept constant, the higher the percentage of silicon the lower the percentage of combined carbon in the casting; and, also, the more rapid the cooling, the greater is the amount of silicon required to prevent more than the desired amount of carbon remaining as combined carbon. Silicon not only tends to change carbon from the combined to the graphitic form, but, when present in increasing amounts, seems more and more to prevent the absorption of carbon or to drive it out, if present. Silicon produces freedom from blowholes and oxides, and makes the iron more fluid. In the following table the perpendicular readings show decrease due to increase in silicon; the horizontal readings show decrease of shrinkage due to size:—

	Total C.	G.C.	C.C.	Si.	S.	P.	Mg.	Depth of chill.	Transverse. 2″ × 1″ × 3″ ins.	Transverse. 2″ × 1″ × 3″ D'fl'ct'n Cwts.	Tensile tons per sq.
No. 1 ..	3.75	3.24	0.51	1.21	0.04	.05	0.70	$\frac{1}{4}$	39.16	0.65	11.90
No. 2 ..	3.82	3.22	0.60	1.20	0.08	.03	0.95		37.96	0.55	11.94

Close grain test-bars.

Relation of Shrinkage to Size and per cent. of Silicon.

Per cent. Silicon.	½ in.	1 in.	2 in.	4 in.
1.00	.183	.158	.130	.102
2.00	.159	.133	.104	.074
2.50	.147	.121	.092	.060
3.00	.134	.108	.077	.045
3.50	.123	.095	.065	.032

As to the effect of combined carbon, we have already discussed the solidification and cooling of cast iron, and it will be remembered that all the carbon which does not precipitate as graphite forms first as austenite, which later decomposes into ferrite and cementite. In short, all the carbon in cast iron will ultimately be found partly in the form of graphite and partly in the form of cementite. The carbon of cementite in cast iron commonly goes under the name of combined carbon, but it must be remembered that cementite is the constituent which gives the observed effects. It naturally follows from this that the strength, hardness and ultimately strength, also the brittleness, of the iron is controlled by this element.

In ordinary castings to be used as cooled from the box, without any further treatment, the com-

bined carbon varies greatly, from, say, 0.1 to 1 per cent.; the carbide of iron, therefore, from 1.5 per cent. to 15 per cent. The amount of this constituent and the nature of its distribution have probably the most powerful influence on the properties of the iron. It is not possible to mix for C.C. because it depends upon the rate of cooling generally the size of the casting and other impurities present.

The writer is of the opinion, along with others, that the exact influence of nearly pure metallic manganese alloyed in varying proportions with nearly pure metallic iron is still unknown. Of course, this element is of more importance to steel makers. Manganese without a doubt increases the total carbon in pig-iron. It also increases the carbon in the combined form, but its influence in this respect is far less than that of the sulphur. Care, however, is necessary, because manganese combined with sulphur as MnS does not increase the proportion of carbon in the combined form, but takes the sulphur out of the form FeS, in which it is most powerful in increasing the C.C. In this sense, therefore, the Mn actually decreases the amount of C.C. Manganese and sulphur both tend to increase the total carbon and the combined carbon, and yet they neutralise each other in this respect. Manganese may, therefore, be called a hardener.

The tendency for the presence of small quantities of sulphur to have a marked effect on the condition of the carbon in cast iron is well known to foundrymen. Sulphur expels carbon from iron at a high temperature, it also turns grey iron white. We may safely say the influence of sulphur upon the formation of graphite is almost the exact opposite of the influence of silicon. That is to say, each increase in the amount of sulphur present increases the amount of combined carbon in the iron. It is usually considered that each 0.01 per cent. of S. will neutralise 15 times as much silicon (*i.e.*, 0.15 per cent.) in its effect upon the condition of the carbon in the iron. It is also important to note that when the S. is in the form of MnS it is not so potent in increasing the amount of C.C. as when in the form of FeS. Sulphur has a tendency to make castings very hard.

Besides the hardening effect of sulphur, it has a deteriorating influence on the properties of cast iron, tending to make it brittle. Excess should be very carefully avoided, and undoubtedly in general foundry work it is desirable to have as little as possible—less than 0.1 and never more than 0.2—for material that has not to be given some further treatment.

The surface of a polished section of iron with 1.0 per cent. of S. presented a very bright even area slightly marked by a very delicate pattern of pearlite. The writer tried one or two specimens containing more than 1 per cent. S., and the whole section was pitted with small holes, increasing greatly in size and number as the S. was increased. The microscopic evidence is that S. in cast iron, when not in excess of, say, 0.8 per cent., separates as sulphide with the cementite-austenite eutectic, mixed with small cementite crystals.

The samples were prepared by grinding on a water-cooled emery-wheel, rotating rapidly by means of an electrical motor. The rubbing was continued on medium emery paper, then on a set of Hubert papers 0-0000, and finally polished on chamois leather, using jewellers' rouge. The etching agent was a 5 per cent. solution of picric acid in alcohol, and etching generally took three to four seconds.

This sulphide is readily found after a little practice, and the position of the pearlite is easily found even by low-power lenses.

Phosphorus, unless in greater amounts than generally found in foundry practice, seems to have little effect on the condition of carbon. But it has the effect of lengthening the period of solidification, and while passing through this stage it certainly gives a longer time in which graphite can precipitate. Phosphorus certainly increases the fluidity of cast iron, and gives it a very fine skin so that a fairly highly-phosphoric mixture gives finer details for ornamental work. Some foundries use up to 2.5 per cent. for this kind of work. For castings of uneven section, like valves to stand steam or hydraulic test, it should not be over 0.7 per cent.

The writer was recently asked how much he would use for ingot moulds for receiving molten steel. Hematite mixtures certainly must be used, keeping P. as low as 0.02 per cent., because in the case of a "sticker" or broken mould the charger can charge the whole lot, steel as well, instead of selling to the mould maker as scrap.

In the case of a number of castings which had broken when nuts were being tightened underneath into position, a few specimens were taken off, polished, etched, and examined under the microscope. The phosphide eutectic was easily recognisable as white dotted areas. In the sample before treatment the peculiar lustre of the fractured metal suggested phosphorus as the cause of the weakness. The proportion of phosphorus was estimated by planimetric measurement, the area occupied by the eutectic averaging about 17½ per cent., and corresponding with about 1.5 per cent. of P., a most undesirable amount.

In order to detect P. in white cast iron, the reagent employed should either colour the cementite before the phosphide area, as does concentrated nitric acid, or it should colour the phosphide area alone, as does neutral sodium picrate.

Discussion.

Mr. Hogg said he wished to put a rather novel question. A certain firm were supplying brake castings similar, for instance, to the brake blocks on electric cars, and they had such faith in the wearing quality of their casting that they were prepared to quote so much per 1,000 miles that the cars ran. The bulk of foundrymen when quoting for castings fixed so much per cwt. He had seen some of these particular castings, and they were really fine. They were hard and chilled on the face, and all through there was a peculiar white crystalline structure. Brake blocks made from castings produced by this particular firm would last double the length of time that a casting made from white iron and 17½ per cent. of steel would. Could the author give them any idea what the mixing of the metal was?

Mr. Hey remarked that he would like to know the author's reason for being dissatisfied with more than 0.7 of phosphorus for hydraulic work. It might not be suitable for some classes of work, but there were plenty of hydraulic castings with more than 0.7 per cent. of phosphorus. The statement was made that cementite was the cause of all brittleness in a casting, but, in his opinion, that was not so. He would contend that phosphorus had something to do with brittleness, and if man-

ganese were used there would be a tendency, under certain conditions, to promote brittleness.

A member remarked that Mr. Timmins spoke of manganese as a hardener. His experience was that it acted as a softener. He had used iron as low as 0.2 manganese, and could not get soft castings, whilst the castings from iron with as high as 2.4 manganese he could very nearly cut. Any of the North Staffordshire irons produced exceptionally soft castings, and yet it was the highest manganese pig there was in the country. On the other hand, going further into the Midlands, or round Derbyshire, the iron was very low in manganese, and there was great difficulty in getting it to work soft unless practically dry sand were used.

Replying to the discussion, MR. TIMMINS said the brake blocks referred to were probably made from washed iron, and the manufacturers were using a re-melted iron.

MR. HOGG: The resultant iron is not so much hard—it has not to be too hard or it would not grip—as that it has a splendid wearing surface.

Replying to a question as to why so much sand was mixed with the pig, the author remarked that if the member saw a piece cut out of the pig bed he would understand why it was. He did not think there was any chance of getting rid of the sand unless it was cast in chills. A great deal of that was done in Sweden.

Penetration of Iron by Hydrogen.

In a paper presented at a recent meeting of the American Iron and Steel Institute, Mr. T. S. Fuller, of the Research Laboratory of the General Electric Company, discussed experiments showing the effect of various conditions on the penetration of iron by nascent hydrogen at temperatures from 20 to 100 deg. C.

It is well known that iron at room temperatures is impermeable to gaseous or molecular hydrogen, but that at higher temperatures it becomes more or less permeable. It is not so well known, perhaps, that iron at room temperature is permeable to nascent or atomic hydrogen.

This paper describes experiments which were performed during an investigation of the penetration of iron by atomic hydrogen at temperatures between 20 deg. and 100 deg. C.

The apparatus used consisted of a 1-16-in. seamless iron tube, plugged at the bottom, and sealed at the top to a glass U tube, having one arm closed and calibrated and the other open. The whole apparatus was completely filled with mercury, and, when in operation, hydrogen penetrated the iron tube, and quickly rose and displaced the mercury in the closed and calibrated arm of the U. A large number of these units were used.

It was found that hydrogen penetrates iron under a great variety of conditions, all of which influence the metal.

(1) The velocity of penetration is greater for a unit immersed, without electrical connections, in 1 per cent. sulphuric acid than for units electrolysed as cathode in a like solution, with such current densities as were tried.

(2) The rate for electrolysed units is influenced by the current—the higher the current, the higher the rate, but the relation is not a straight-line function.

(3) The penetration velocity increases with each successive electrolysis, provided rest periods do not intervene, or with acid "pickling."

(4) The effect of rest or moderate heating upon units which have been electrolysed or pickled is to restore the orignal resistance of the iron to the passage of hydrogen.

(5) Temperature has a marked effect, the rate of penetration increasing with the temperature. The rate of 90 deg. C. for an iron unit made cathode in 1 per cent. sulphuric acid with a current = 0.2 amp. is 14 times its rate under similar conditions at 20 deg. C.

(6) The velocities of penetration for units electrolysed in 1 per cent. solutions of potassium sulphate and sodium hydroxide, and in tap water, are about equal, and are 1-12th to 1-15th the velocity of units electrolysed in 1 per cent. sulphuric acid.

(7) Hydrogen produced by the reaction between tap water at temperatures from 50 to 100 deg. C. and iron, or between steam and iron, penetrates the metal at a rate depending directly upon the temperature.

(8) The velocity of penetration for 3 per cent. nickel steel is the same as that for iron.

(9) Hydrogen does not penetrate copper at a temperature of 20 deg. C.

(10) The rate for tinned iron is greater than for iron, and for galvanised, sherardised, and coppered iron is less.

(11) No evidence of sulphates could be found inside a unit which had been pickled in sulphuric acid and in which 2.4 cc. of hydrogen had collected.

(12) No hydrogen penetrated a unit immersed in a solution of 1 per cent. sulphuric acid plus 1 per cent. potassium dichromate in 96 hours.

(13) The gas which was collected in one of the units was analysed and found to contain 95 per cent. hydrogen and 5 per cent. of an uncombustible gas, possibly nitrogen.

The following explanation of the manner in which hydrogen is forced through iron tubes having walls 1-16 in. in thickness is offered:—Atomic hydrogen which has been liberated by the current, in the case of units which were electrolysed, or by the reaction between metal and solution, in the case of units which were not electrolysed, penetrates the surface of the iron where gaseous or molecular hydrogen is later formed. Iron at room temperatures is impermeable to the latter. The atomic hydrogen continues to penetrate the surface of the metal rapidly and to form molecular hydrogen. The latter can escape only very slowly and as a pressure, sufficient to force the gas through the metal, is built up. It is a pressure built up in this way which also results in the well-known phenomenon of the cracking of hardened steel when "pickled" in acid.

MACHINE TOOLS.—In some remarks contributed to the discussion on Sir Alfred Herbert's Paper on "Machine Tools," read before the North-East Coast Institution of Engineers and Shipbuilders, Professor W. M. Flinders Petrie said that, regarding priority in the use of some machine tools, Whitworth, with his accurate facing plates, was not the father of mechanical accuracy. The Egyptians in 4700 B.C. habitually used great facing plates several feet wide, smeared with red ochre, to test the truth of large rock foundations and all fine-joint surfaces of stone. They required the stone face to catch the ochre at spots not more than an inch apart all over. Later on, about 3400 B.C., there was a granite sarcophagus nearly 9 ft. long, with errors from true planes averaging 5-thousandths of an inch. Coming to the drawing-office, the Egyptians used large sheets of squared papyrus ruled in red for scale drawings of work, showing joints and details of construction. For drilling hard rocks tubular drills were commonly used, armed with cutting points which could slice through quartz crystal. The regularity of the cores commanded the admiration of the modern engineer. Copper saws over 8 ft. long were similarly armed for slicing granite.

Diesel Engine Castings.

By F. J. Cook.*

In cast iron when it is cooling down from the molten to the solid state, the planes of crystallisation group themselves perpendicularly to the surface of the external contour, that is to say, at right angles to the outside surface and in the direction in which the heat of the fluid cast iron has passed outward from the body in cooling and solidifying.

Every abrupt variation in the external contour, every salient and every re-entering angle, no matter how small, upon the surface of a casting, is attended with an equally marked sudden alteration in the arrangement of the crystals of the metal. In the neighbourhood of each such point of variation there occurs a confused and irregular formation of crystallisation, so that the proper interlocking of the crystals is prevented and lines of weak and loosely packed crystals, if not actual cavities, are produced.

There are castings of this character which, on account of the static pressure of the metal in the mould when casting, or some other cause, artificial or accidental, do not show these weaknesses in any marked degree; but when such castings are exposed to repeated

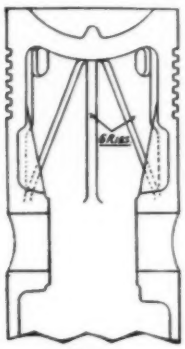


FIG. 1.

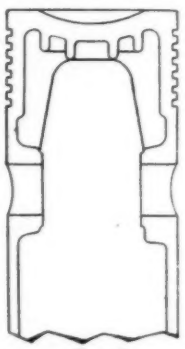


FIG. 2.

heating the crystals change position and form the same loose and confused mass, with the consequent weakening of the structure.

The natural remedy for this, therefore, is to avoid all sharp angles, ribs, and sudden deviations of sectional outline, so that the metal while being poured may be allowed to flow in natural curved lines. These remarks are equally true of castings in general, but are of primary importance in the design of Diesel engine pistons and cylinder heads.

Figs. 1, 2, and 3 represent designs of Diesel engine pistons which have been culled from the illustrations of these parts appearing in technical journals. In the light of what has been previously said, it is apparent that the castings, on account of the ribs, are not only subject to the effects of bad crystallisation mentioned, but also have the disadvantage of being subjected to high initial cooling strains which further increase the liability to cracking when in use.

Fig. 4 shows a much improved design, there being quite an absence of anything that will retard a natural formation and an even cooling down in the casting. This design has been quite successful in ordinary work. By designing the under side of the head straight, as in Fig. 5, a further improvement has been effected. Such a formation allows a more easy passage for dissipation of the heat to the outside cooling surface provided for by the water-cooled liner, as indicated by the arrows. This type has given excellent results during the war in submarine work.

It is essential that there be a good easy angle at the point marked A in order to avoid a too abrupt change of section. Also, an angle at the bottom of the cut-away B (where such is required to miss the valves in the cylinder cover) is most desirable, for it must be remembered that a definite sudden change in contour brought about by a sharp corner forms a point from which a crack is very likely to start.

Every advantage should be taken of any process in manufacture that will facilitate closeness of grain with its consequent close packing and greater cohesion of the crystals. It is therefore advantageous to cast the cylinder liners and pistons on end, with the breach end at the bottom, thus taking advantage of the static pressure of the metal in the mould. Denseners also have been used for improving the compactness of the piston head, but the use of these require special care or hardness will be overdone.

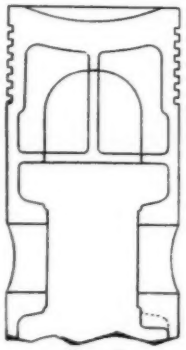


FIG. 3.

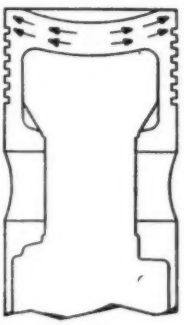


FIG. 4.

Hardness is a point which requires very careful watching in this class of work, as a cast-iron piston if too hard, has a tendency to split right across when first put to work, particularly if it is subjected to full load soon after starting. A tough iron therefore is more desirable.

The properties of cast iron which are essential to successful working of Diesel engine pistons and liners are: High tensile and other physical properties; metal which will readily take a high polish under working conditions and thus give good resistance to wear, and the ability to resist growth and cracking when subjected to the high working temperatures which are a feature of this class of engine. These conditions are only met with in cast iron possessing the highest intercrystalline cohesion, and this is also associated with metal which gives the highest tensile strength. It is a remarkable and fortunate circumstance that all these desirable qualities are associated with cast iron in proportion to its tensile strength. This naturally narrows the choice, and materially assists in determining the proper metal to be used.

The factors which tend to give a cast iron having the highest physical properties are:—

(1) Chemical composition.
(2) Casting temperature.
(3) Rate of cooling.
(4) Microstructure.

It is essential to take into account the rate of cooling

* North-East Coast Institution of Engineers and Shipbuilders Bolbec Hall, Newcastle-upon-Tyne.

when considering the chemical composition of metal to be employed in any given casting. For the purposes of this Paper, therefore, the proportions of the various chemical elements suggested are based upon those which will give the highest tensile strength on a bar cast 1¼ inches diameter parallel and turned down to ½ a square inch or thereabouts in the centre.

Carbon.—The most important element in cast-iron is carbon. It is not too much to say that all the physical properties of the metal depend upon the quantity of this element present and its condition, the value of the other elements being in accordance with the effect they have on the carbon and the compounds it forms. It is very seldom that one finds any *particular* mention of the *total* quantity of carbon present, whilst the quantity of combined carbon advisable is quite glibly spoken of. Yet it must be obvious that with the same percentage of combined carbon present there must be a great difference in the condition of the metal if the total carbon varies, say, from 3 to 3.75 per cent., particularly when Dr. Stead† has shown examples where an increase of each 0.1 per cent. of graphite has reduced transverse strength of 2 cwts. and tensile strength by 0.8 tons per square inch.

Professor Turner, in his admirable book, "The Metallurgy of Iron" (p. 251), states that maximum tensile strength is associated with 0.47 per cent. of combined carbon and maximum transverse strength with 0.7 per cent. The author's experience, however, leads him to the conclusion that these figures for

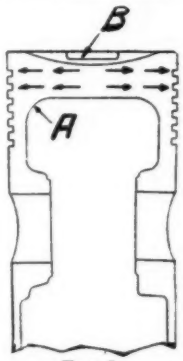


FIG. 5.

present day practice should be reversed, maximum tensile strength being obtained with 0.6 to 0.8 per cent. and maximum transverse strength with 0.4 to 0.6 per cent. and with total carbon not exceeding 3.25 per cent.

Silicon.—One of the most important elements in determining the suitability of cast iron for any given purpose is silicon. This element is always present, in proportions most variable, whilst the influence it exerts on the condition of the carbon present, and consequently on the hardness and fluidity of the metal, is most marked. Professor Turner's research on the effects of this element on cast iron, though made some 30 years or so ago, has stood the test of time, and, probably it is not too much to say, laid the foundation for the application of the science of chemistry to practical working in cast iron.

As the quantity and condition of the carbon have been stated to be so important, whilst the effect of silicon on this element is so marked, it is clear that if a formula can be adduced that will show when these two elements are in the best proportions for any given class of work, a very important stage will have been reached. With this object in view, the author has adopted the following more or less empirical formula, based upon the amount of carbon in the pearlite, and he has used it with marked success in practical working :—

$$Sc = \frac{C}{4{\cdot}26 - \frac{Sil}{3{\cdot}6}}$$

Where Sc = ratio of silicon to carbon.
c = *total* carbon in percentage.
sil = silicon in percentage.

The elements carbon and silicon are in the best proportion for Diesel-engine pistons and liners and all parts requiring highest tensile strength when the value of Sc = 0.76 to 0.82, and for water-cooled cylinder heads and castings requiring maximum transverse strength when the value of Sc = 0.83.

Sulphur.—By many, sulphur is looked upon as the arch-enemy of the ironfounder; but although its presence makes the molten metal thick and sluggish, thus giving rise to blow-holes, this element, in fair proportions—say, 0.12 per cent.—adds considerably to the wearing properties and strength of the metal. In every case, however, sulphury iron *must* be cast as hot as possible if trouble is to be avoided.

Phosphorus.—There are many who think it impossible to produce strong irons without the percentage of phosphorus being very low. To lower this element they frequently resort to hematites, but these, with their high percentage of total carbon, often do more harm than a liberal amount of phosphorus would. When the proportions of total carbon and silicon are

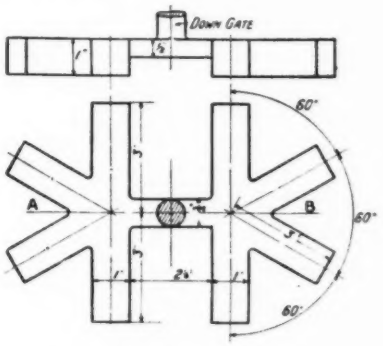


FIG. 6.

those required for maximum tensile strength—as in the formula given earlier in this Paper—the proportion of phosphorus may be as high as 1 per cent. without seriously jeopardising the tensile strength; in fact, with steam cylinders and castings requiring maximum strength and of complicated design the reduction of shrinkage and the additional fluidity of the metal due to this percentage will generally result in a sounder casting, with fewer initial contraction strains. Where the ratio of silicon and carbon is different from that which has been suggested, the quantity of phosphorus becomes one of the vital elements and must then be kept as low as possible.

In the early part of this Paper reference was made to the fact that only two investigators were known to the author to have dealt with this particular problem. One of these, Mr. J. Edgar Hurst, has contributed two excellent Papers* in which he has dealt in an exhaustive manner with many of the troubles to be met with in cast-iron in the working of Diesel engines. One of the conclusions he has arrived at is that a high percentage of phosphorus is detrimental in this class of work.

† British Foundrymen's Association *Proceedings*, 1915.

* Manchester Association of Mechanical Engineers' "Proceedings," 1916. Institution of British Foundrymen's "Proceedings," 1917-18

Unfortunately, the chemical analyses and physical properties given by Mr. Hurst do not fulfil the requirements of the formula which has been stated and thus, the compositon having started from a poor basis, the quantity of phosphorus has become of critical importance.

Table I., which contains part of the information gleaned by the author from several years' study of British and Continental results, goes to show that where the silicon and carbon are in the desired ratios, the quantity of phosphorus present does not become so extremely important.

The second column gives particulars of a piston in a German-made engine. This engine has given reasonably good results and is still at work. After about six months running the pistons were found to be slightly deformed, and showed signs of wear, but they would generally be classed as good. In the engine of German make dealt with in the third column, the piston did not last six months, having worn badly and star-cracked, but certainly not because the phosphorus was not low enough or the manganese not sufficiently high. With the next engine, described as "Continental," the results in working were bad from the first. Without any alteration of design, and specially to prove the effects of phosphorus, the replace pistons were made with this element as high as 1.34 per cent. but with a silico-carbon ratio to satisfy the formula, whilst the manganese was very low, being only 0.28 per cent. These pistons are still giving excellent results, and the engineer's first report was that they ran better than the original ones had ever done. The engines of the type dealt with in the sixth column and described as "Scotch" have also given excellent results. Many pistons of this class of metal were employed in submarine work during the war. The last column contains the corresponding particulars recommended by the author.

TABLE I.

	Suggested by Hurst.	German.	Another German.	Continental.	Replaced by	Scotch.	Suggested by the Author.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Phos. ..	0.52	0.33	0.59	0.54	1.34	0.54	not over 1
Mang. ..	1.44	0.72	0.99	1.08	0.28	0.97	not over .5
Sc. ..	0.9	0.83	0.91	0.92	0.8	0.77	0.76-0.82
Results .	—	good	bad	bad	good	good	has never given star cracks, low tensile results, or bad wearing qualities.

In each of the instances cited—and many more could be given if necessary—the results in actual working bore no relation to either the phosphorus or the manganese content of the metal, but were closely related to the results suggested by the silico-carbon ratio.

Manganese has a tendency to harden the iron both directly and by causing the carbon to remain in the combined form. In the presence of much sulphur, however, it may act as a softener by uniting with that element and forming manganese sulphide, which rises to the top of the metal and passes away with the slag. When adding the manganese to the metal, in the form of ferro-manganese, in the ladle it is necessary that the metal be very hot and that sufficient time be allowed for the change to take place, otherwise the manganese-sulphide will be found in the top part of the casting in the form of very hard spots, which are difficult, if not impossible, to tool by ordinary methods. The general properties of the metal—other than a tendency to chill—are not materially affected so long as the manganese is not in greater proportion than 0.7 per cent For castings in the making of which denseners are employed on faces which have to be machined, it is not advisable to have more than 0.4 per cent.; otherwise there will be a tendency to chilling.

As manganese tends to the removal of sulphur and the formation of brittle spikey crystals, which break off under rubbing, much of this element is not good for castings which are required to have good wearing properties when working under heated conditions.

To sum up, the proportions of the various chemical elements which the author has found to give good results for Diesel engine cylinder liners and pistons are :—

Total carbon	=	3 to 3.2 per cent.
Silicon	=	1 to 1.2 per cent.
Phos.	=	not over 1 per cent.
Sulphur	=	0.12 per cent.
Manganese	=	not over 0.5 per cent.

For cylinder covers, which require to be not quite so hard for wearing purposes, and in which metal with rather less contraction is desired, the silicon can with advantage be increased to 1.5 per cent. and the manganese to 1 per cent.

After twenty years' experience with this class of metal the author finds that the most advantageous amount of steel to be added to the mixture is 15 per cent. Experiments with varying amounts up to 40 per cent. have been made, but with above 15 per cent. the metal has a tendency to be too hard, which is very undesirable for this class of work. Further improvement will probably be gained by the addition of some of the rarer elements, and in this direction vanadium-chrome or nickel-chrome seems to hold out some prospects of success.

Surface Wear.—There is much room for investigation into the subject of surface disintegration and wear of cylinders and all rubbing surfaces of cast-iron. When cast-iron is machined by the ordinary cutting methods there is more or less tearing away of the crystals. The tearing out of the softer material produces cracks or indentations and leaves the harder constituents standing up in relief. The degree or fineness of the finish will depend upon the structure of the material and the speed at which the material was cut; generally speaking, according to Professor Poliakoff* the quality of the finish will be improved as the cutting speed decreases. The resistance to wear under working conditions depends upon how far the crystals will resist breaking off—thus forming a hard, gritty abrasive substance which increases the wear—or will spread over and form a highly polished surface. The existence of large pearlite areas, with small areas of harder constituents and fine graphite, has a marked effect in bringing about the latter condition.

Grinding of cylinder liners and piston rings, being less drastic and exposing less of the harder crystals, appears to be a desirable method of finishing these articles, provided every trace of emery be removed. Where this is not practicable, very slow cutting speed and fine feeds for finishing should be resorted to with the object of decreasing the wear.

Annealing.—Considering the enormous quantities of heat which the pistons and cylinder heads have to deal with, it is imperative that everything in the nature of cooling strains in the castings should be eliminated, so that the crystallisation shall be in its natural formation, allowing free and ample expansion. As all castings are more or less subject to initial strains, it is desirable that those having to work under heated conditions should undergo some heat treatment or annealing. It is to be feared, however, that frequently more harm than good is done owing to a general lack of knowledge of what is desired and of the results generally accruing from heat treatment of cast-iron,

* Manchester Association of Engineers. 1915.

and to the crude manner in which the heat treatment is performed.

Dr. Hatfield† has carried out quite a large number of experiments showing the effects of heat treatment of cast-iron which are well worth the attention of those who have to do with Diesel-engine castings. Whilst heat treatment of cast-iron, even at a low temperature, affects the physical properties of the metal, a prolonged treatment at 780 deg. C. is positively dangerous, as, among other things, the pearlite is then broken down and the generally desirable physical properties of the metal are destroyed.

Table II. gives the results of annealing on the physical properties of a few out of many test bars of cast-iron of the composition recommended by the author. These tests have been carried out by Mr. J. J. Howell, of Birmingham. The heat treatment to

TABLE II.

Test No.		Tensile Strength. Tons per square inch.	Transverse Strength. Cwts. 1′ sq. bar, 12″ centre.	Impact.	Hardness.
1	As cast ..	17.0	35.5	65	77
	Annealed	13.7	32.0	60	44
2	As cast ..	16.9	31.25	45	84
	Annealed	13.5	27.5	50	39
3	As cast ..	17.8	33.75	70	80
	Annealed	13.77	28.25	60	67

which the castings have been subjected consists of gradually raising the temperature to 600 deg. C., retaining that heat over six hours and cooling down in the furnace over a period of 48 hours

The tensile test bars were cast $1\frac{1}{4}$ in. diameter, turned down after annealing to $\frac{1}{2}$ square inch area in centre before testing. The transverse bars were cast $\frac{1}{2}$ in. square, machined to 1 in. square, and tested on 12 in. centres. The impact bars and tests were in accordance with the notes on impact given later in this Paper. The hardness numeral was obtained by the drill method.

It will be observed that in every case the physical properties have deteriorated. The same heat treatment continued for half the length of time would in all probability be sufficient to remove the casting strains in cylinder heads and pistons, with a corresponding decrease in the deterioration of the physical properties. Considering the cooling effects the cylinder liner receives when at work, and bearing in mind that it is less subject to initial casting strains, the author does not consider heat treatment of these parts necessary.

TABLE III.

Test No.		Tensile Strength. Tons per square inch.	Transverse Strength. Cwts. 1′ sq. bar 12″ centre.	Impact.	Hardness.
4	As cast ..	17.3	34.75	75	82
	Annealed	15.49	33.50	55	97
5	As cast ..	17.8	32.0	70	78
	Annealed	14.4	30.75	60	110

It is essential that the heat treatment shall be carried out in a properly designed furnace. Owing to the castings to be treated being generally too large to allow of their being packed in pans and surrounded with suitable packing they should only be subjected to radiated heat. If they are exposed to the action of a coal-fire flame, deterioration of a serious nature will take place, as shown in Table III. The composition of metal as cast was as recommended for cylinder heads, temperature and time of heat treatment, size of bars, and method of testing being the same as in Table II.

The most notable change shown is the increase in hardness, which has previously been pointed out as being a very important condition.

The alterations in chemical composition of the parts of the bars subjected to the action of the flame were :—

Total carbon decrease from 3.163 per cent. to 3.027 per cent.

Sulphur increased from 0.112 per cent. to 0.17 per cent.

Silicon decreased from 1.586 per cent. to 1.306 per cent.

Tests.

Two useful workshop tests—with the class of iron suggested—for the guidance of the founders are : Impact test and casting temperature.

Impact Test.—Whilst impact testing is not usually applied to cast iron, it is, however, beginning to be used, particularly on the Continent, in connection with Diesel-engine work. Whilst the Izod method of testing is more applicable to brittle substances, and should therefore be of use for cast iron, the practical limits as to the size of the bar are too low to give correct indications for this class of work. The sections of Diesel-engine parts, particularly the piston heads, are very thick, and it is more advisable to test the metal under nearly similar conditions.

A satisfactory test is on bars 40 mm. square (1.57 in.) supported on knife edges 160 mm. (6.3 in.) apart, and by dropping a weight of 12 kilos (26.5 lbs.) from a height of 30 cm. (11.8 in.), increasing the height of drop by increments of 5 cm. (1.9 in.) until the sample breaks, the height of drop at which the bar eventually fractures being taken as the impact figure. Attached to the weight, in such a manner as to strike the bar parallel to the supporting knife edges, and at the centre, is another knife edge. The face of each knife edge should be rounded $1\frac{1}{16}$ in. radius.

A result of 55 cm. (21.5 in.) is considered none too high for this class of work, although this is quite a severe test. The maximum attained, as far as the author knows, has been 80 cm. (31.3 in.) Some recent results obtained with iron conforming to the suggested conditions are shown in Table II.

Casting Temperature.—For many years foundrymen have been well conversant with the fact that casting temperature has a marked effect upon the physical properties of cast metals, but it was not until the important research of Dr. Longmuir* that anything like exact results were obtained. Many of those results were at the time certainly startling. In connection with the casting of high-class metals of the cast-iron series there is undoubtedly a great need for a handy practical optical pyrometer. For small quantities of metal the "Foster" pyrometer is very convenient, but for large quantities of metal it is of very little use.

Low silicon and low total carbon cast iron are very susceptible to the effects of casting temperature, and some irons employed for such purposes are also liable to liquid contraction. A handy workshop test for casting temperature with this class of iron, one which the author has used successfully for many years, consists in making bars of the general dimensions shown in Fig. 6. When cold, the bars are broken through the line A.B., the condition of the fracture giving an indication of the temperature at which the metal was poured. Passing from the correct temperature (which is usually as hot as can be obtained from the cupola) to a very low one, the following fractures will be observed. Perfectly solid and homogeneous; then slight whitish centre; then brown centres of varying sizes and depth of colour, as temperature is lowered, and then black centre. With the latter are always associated open cavities, and immediately above each cavity is invariably found a gas hole.

† Hatfield Iron and Steel Institute "Proceedings,"1907.

* Iron and Steel Institute; Carnegie Memoirs.

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NOTES AND COMMENTS.

The extensive developments during recent years in the use of permament moulds or dies for the production of castings in non-ferrous metals and alloys has resulted in considerable attention being given to their extended use in the production of castings in grey cast-iron.

The use of permanent moulds for the production of special castings in grey iron is not new, and they have been adopted fairly extensively in foundries for the production of certain classes of castings. For the most part their use has been confined to massive castings of large cross-section which are required internally sound and scrupulously free from porosity. In addition, castings required with a chilled surface or castings in which a chilled surface is immaterial are extensively produced in permanent moulds, dies, or chills. Examples of both types of castings are to be found in gear banks, chilled wheels, and firebars, whilst large chilled rolls are cast in what are virtually permanent moulds.

In a recent issue of this journal the adoption of permanent moulds for the production of piston ring sleeve castings by the Daimler Motor Company was indicated. In America considerable work has been done and the commercial production of castings in permanent moulds has been carried out more or less extensively by Outerbridge and also by Custer. It is also proposed to establish a foundry for the complete production of ordinary radiator sections by a method embodying the use of permanent moulds.

The application of permanent-mould systems to the production of standardised articles in grey cast-iron has many inherent possibilities. Apart from the metallurgical value and possibilities the fact that the adoption of permanent moulds places the production of sound castings free from the many annoying defects, of good surface appearance and correct to form and shape, entirely apart from the skill and care of an individual craftsman appears to us to hold out by far the greatest attraction.

In spite of this the development of the use of permanent moulds for the production of grey iron-castings has not taken place to anything like the same extent as in the non-ferrous metal industry. There appear to be at least two fundamental reasons for this lack of development. These are the comparatively high temperature of molten cast-iron as compared with the majority of non-ferrous metals and the difficulty encountered in the production of soft grey castings entirely and reliably free from the presence of the hard unmachinable chilled portions, particularly at the edges and at abrupt changes in section of the castings. This latter is peculiar to cast iron, and is not met with in the non-ferrous alloys.

The presence of the chilled white-iron structure in castings which require to be machined is fatal, and this is the primary reason given by H. E. Diller in a consideration of the development of permanent-mould casting. This writer, in a recent issue of our American contemporary, states that whatever the silicon-content of the iron, there is always the danger and uncertainty regarding the presence of chill at the edges and corners of the castings.

Many metallurgists and foundrymen consider that the prevention of the occurrence of chill in permanent-mould castings lies in the rapidity of extracting the castings from the mould after pouring. A consideration of the phenomena of graphitisation in cast iron would appear to show that this opinion is not well founded. In alloys containing silicon the greater portion of the graphitisation appears to occur during the latter period of the solidification of the alloy from the molten state. This is indicated by the cooling curves of these alloys. Under these circumstances the rate at which this solidification period is traversed would appear to determine the presence or absenoe of chill,

and hence the rapid removal of a casting which, in any event, must take place after the casting has solidified, can have little influence in preventing the formation of chill.

It would appear from these premises that in a cast iron of a given composition the features controlling the presence of chill are those which govern the solidification during this period. These features are the temperature of the metal poured into the mould and the temperature of the mould itself. By arranging to have the mould at any given temperature almost any degree of rate of cooling throughout the solidification range could be obtained.

This problem of determining the rates of cooling of molten cast-iron which will produce chill is one which is well worthy of the attention of research bodies and institutions interested in cast iron. We venture to assert that the data obtained would almost instantly be of immense industrial value, and would be a step in advance in the development of permanent mould casting in grey iron.

The high molten metal temperatures to be dealt with in the case of cast iron make the problem of a suitable mould material somewhat more difficult than in the case of the majority of non-ferrous materials. At the present time it appears to be generally acknowledged that a high-grade cast-iron is the most suitable material for the construction of dies. There is still, however, quite a wide field for research in this direction, both with the object of improving the life of cast-iron dies and also of determining an effective substitute for this material.

THE EDITOR.

The Institute of Metals.

An invitation from the Mayor and Corporation of Barrow-in-Furness to hold the annual autumn meeting of the Institute of Metals in that town on Wednesday and Thursday, September 15 and 16 next, has been accepted by the Council of the Institute. Particulars of the meeting can be obtained from the Secretary, Mr. G. Shaw Scott, M.Sc., 36, Victoria Street, S.W.1, who will also be glad to forward tickets for the tenth annual May lecture, which will be delivered by Professor C. A. F. Benedicks, Ph.D., Stockholm, Sweden, at 8 p.m., on June 10, at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1, the subject of the lecture being "The Recent Progress in Thermo-Electricity." The President, Engineer Vice-Admiral Sir George Goodwin, K.C.B., LL.D., will preside, and light refreshments will be provided after the lecture. Prior to the lecture a ballot for the election of members and students will take place. Persons so elected will be entitled to be present in their capacity as members or students respectively, both at the lecture and at the Barrow meeting, whilst their first annual subscription will cover the extended period ending June 30, 1921. Membership forms, or copies of the new illustrated membership booklet, can be obtained from the above address. An additional advantage of membership of the Institute of Metals has just been conceded by the Council. It has been arranged that members and students of the Institute are henceforth at liberty to attend the meetings of any of the several local sections which exist throughout the country without further payment beyond their ordinary subscriptions to the Institute. Members and students receive cards of admission to and programmes of, the meetings of the various local sections.

Australian Steel Works.

The Agent-General for Queensland, 409, Strand, W.C.2, as the London representative of the Government of that State, has now detailed information concerning the scheme of steelworks to be established at Bowen. The scheme is to include :—(1) A blast furnace plant, to produce 350 tons of pig-iron per day, with slag cement; (2) a battery of by-product ovens to supply coke both for the blast furnace and sale; (3) four open-hearth steel furnaces, each of 60-ton capacity, with hot metal mixer of 500-ton capacity; (4) a blooming mill, electrically driven; (5) a combination rail and structural mill. The plant to be erected will have a capacity of from 800 to 1,000 tons of rails per day when required.

Fuel Oils in Sweden.

According to a report from Sweden, the Swedish Board of Trade has issued a report on the regulation of the market for imported fuel oils, and sulphite alcohol used as a motor fuel. The Board points out that the conditions for the distribution of liquid fuel are at present unfavourable, the chief inconvenience being that the Swedish fuel market is dependent on a small number of oil trusts. The remedy this evil, the Board recommends the acquisition by Sweden of foreign oil wells, the construction of a fleet of tank steamers of her own and the erection of oil refineries. For the transport of oil to Sweden two boats with an aggregate dead weight capacity of 12,000 tons are considered sufficient. The total cost of the two vessels is estimated at about Kr. 10,800,000.

Asbestos in Arizona.

The Bureau of Mines reports the discovery of an extensive asbestos claim in Arizona. The deposit is on an Indian Reservation, and under the present law development work cannot be undertaken. The American Consul at Chungking, China, reports the discovery of asbestos in Yachow and the mountains around Ta-chien-lu, although mineral specialists have not yet investigated the value of the discovery. An asbestos plant in Italy has recently begun the manufacture of asbestos pipe from Portland cement and asbestos, which is said to be lighter than iron pipe, acid proof, and corrosive proof and able to bear 450 lbs. pressure per square inch. The cost of manufacture is said to be one-third of the net selling price of English iron pipe. The same company has also begun the manufacture of wall tile similar in composition to the pipe.

Luxemburg Furnaces Idle.

The two blast furnaces which were blown in a month ago at the Société des Terres-Rouges at Esch have had to be damped down again for want of coke, and two furnaces have been damped down at the Burbach Works at Esch. Of the forty-nine furnaces in Luxemburg, only four are in full operation.

Books Received.

Weights of Steel Bars Sections and Plate Tables. By T. STOBBS. E. and F. N. Spon, Limited, 57, Haymarket, London, S.W.1.—The tables have been compiled for the use of manufacturers and merchants, besides offices, shops, rod mills, tyre mills, forges, and foundries. The tables cover English and metric sizes, weights of sections in pounds per lineal foot, and kilograms per metre length. For square, round, hexagon, octagon, three square, quarter-octagon, half-round, oval, flats, etc.; and tables for cogged bars, for calculating the weight of tyres and tyre lumps, large forgings and castings in steel. A large and varied number of examples, worked out in English and metric sizes and weights in lbs., and in metric sizes and weights in kilos, are given in the first part of the book.

Heat Treatment Bulletin, No. 21, dealing with the Wild-Barfield patent electric furnaces.

Catalogue Received.

Sturtevant Engineering Company, Limited, 147, Queen Victoria Street, London, E.C.4.—Copy of catalogue No. 1,072 on mechanical draught for boilers. This catalogue has been brought up to date and deals very exhaustively with this subject. Copies of the catalogue and any further information will be gladly forwarded to those interested in this matter.

The Ironfoundries of Messrs. Glenfield & Kennedy, Limited.

The iron foundry is the subject of a great deal of attention on the part of engineers at the present time, and its importance in an engineering establishment is becoming more fully appreciated.

By the courtesy of Messrs. Glenfield & Kennedy, Limited, engineers and ironfounders, Kilmarnock, Scotland, we are enabled to give the following details of their two foundries, which are equipped with the most up-to-date appliances for the production of iron castings.

The foundries were designed to deal with heavy and light castings respectively, and their individual requirements have received special consideration in the lay-out of the plant and buildings.

The heavy-foundry building covers an area of 4,223 sq. yds., and is divided into three bays, each 250 ft. in length. The width of the main bay is 65 ft., and has a height, to the overhead crane rails, of 60 ft. The height of the other bays is 40 ft. Fig. 1 gives a view of the large bay in the heavy foundry, showing one of the two 60-ton travelling cranes. The ample equipment of hydraulic side cranes of various capacities ranging from 5 to 9 tons is well illustrated in this view, and they are disposed in such a manner as to enable the moulding operations to be carried out with the minimum of labour. Jolt-ramming machines capable of handling moulds for casting from 10 cwts. up to 6 tons are installed in the various bays. Special facilities are also arranged for extensive loam moulding in this department.

In their principal business as hydraulic engineers Messrs. Glenfield & Kennedy, Limited, are continually producing large heavy hydraulic rams and cylinders. For the production of these large castings with the requisite degree of soundness and freedom from porosity and other defects, it has been found necessary to cast them vertically in dry sand moulds, allowing a large sinking head. For this class of work a casting pit 30 ft. deep has been provided, permitting the production of hydraulic rams up to 40 ft. in length. A view of this casting pit in the heavy foundry is shown in Fig. 2.

The light foundry illustrated in Fig. 3 has an area of 4,760 sq. yds., and is divided into four bays, 250 ft. in length. The main bay is 45 ft. in width, and has a height of 40 ft., the remaining bays being 28 ft. high. A full complement of cranes is provided, consisting of 15-ton overhead electric travelling crane and hydraulic wall cranes of capacities ranging from 1 to 5 tons.

FIG. 1.—SHOWING HEAVY FOUNDRY WITH HYDRAULIC SIDE-CRANES.

The class of work dealt with in this foundry is very adaptable for machine moulding, and considerable economies have been effected by their use. Jolt rammers of capacities from 10 cwts. up to 4 tons are arranged in the various bays, and a complete installation of moulding machines of various types, including portable, turn-over, hand-squeezers for plate work, ramming machines, pattern-draw machines, and rock-over-drop moulding machines is provided.

Hot-air type drying stoves are arranged in each of the foundries, and are designed of such a capacity as to accommodate the largest cores and moulds. The floor drying of moulds is entirely dispensed with. Each stove is in itself a complete unit, thus allowing of any individual drying chamber being used alone.

The foundries are well lighted, and a modern system of ventilation and heating has been installed throughout. Hydraulic and pneumatic mains are laid throughout the bays serving the various machines, cranes and tools where required.

of the firm's locomotives, one of which carries a jib crane attachment.

The two foundries together produce about 15,000 tons per annum, and single castings of up to 27 tons are made.

FIG. 2.—VIEW OF HEAVY-CASTING PIT.

The foundries are served by five cupolas, four having a melting capacity of about 10 tons per hour, the remaining one, which is of small diameter, having a melting capacity of 1 ton per hour, is used for special melts and for experimental purposes.

Both the raw material and also the finished castings are the subject of strict scientific control. The chief chemist works in conjunction with the foundry manager and his staff of qualified metallurgical and analytical chemists make regular daily analyses of both the raw

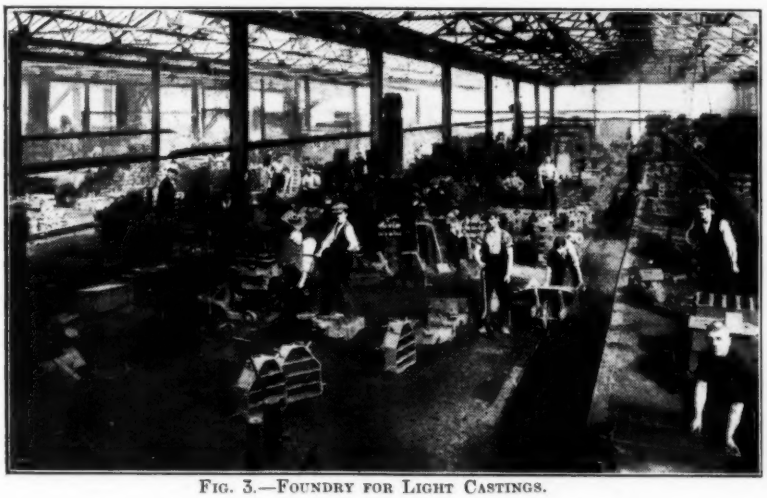


FIG. 3.—FOUNDRY FOR LIGHT CASTINGS.

A spacious stockyard surrounds the foundries, a view of which is shown in Fig. 4. The yard is laid out to enable the raw material to be handled conveniently and economically, and a broad-gauge railway is provided for transport purposes between the various sections of the works. This is carried out, utilising two

material and the finished castings, and no effort is spared to maintain both the quality of the metal and castings at the highest standard of excellence. Test pieces for both tensile and transverse tests are taken daily, and they are thus enabled to guarantee castings to fulfil such specified requirements as they undertake.

XUM

Institution of British Foundrymen.

SCOTTISH BRANCH.

The Annual Meeting of the Scottish Branch was held on March 27, Mr. Bell (Branch President) in the chair.

Reports were submitted from the Secretary and from the Treasurer showing the Scottish Branch to be in a fairly healthy condition. The papers read before the Branch were of a very high order, and the Branch was in a good position financially. The following office-bearers were elected:—President, Mr. A. Fraser; Vice-Presidents, Messrs. H. Williamson and H. M. Hodgert; Hon. Secretary, Mr. John MacFarlane, 3, Sharrocks Street, Ibrox; Hon. Treasurer, Mr. John Logan; Members of Council, Messrs. A. Lawrie, W. Thomson, J. Smith, Allan Ure, Tom Mayer, A. Y. Wilson, G. Mackay, A. Mearns, and A. Cree.

After the business was transacted, the meeting resolved itself into an ordinary meeting of the Branch, when Mr. G. W. Tyrrell, of the Glasgow University, delivered a lecture on "The Geological Examination of Moulding Sands." The lecturer at the outset stated that within recent years a great amount of research work had been carried through with regard to moulding sands, and in this connection he wished to draw attention to a work recently published on the subject by Mr. Boswell, with whom he had been to a degree associated. The chief duty of the geologist with regard to moulding sands was to try and discover local sand of a suitable character for certain work, and in this way the cost of work might be reduced. To the geologist sand was quite a definite material, and for the purpose of grading the following classification had been established:—

Gravel.—Particles of broken rock whose average diameter is greater than 2 millimetres.

Very Coarse Sand.—Particles whose average diameter is greater than 1 mm. and less than 2 mm.

Coarse Sand.—Greater than 0.5 mm. and less than 1 mm.

Medium Sand.—Greater than 0.25 mm. and less than 0.5 mm.

Fine Sand.—Greater than 0.1 mm. and less than 0.25 mm.

Silt.—Greater than 0.01 mm. and less than 0.1 mm.

Clay.—Less than 0.01 mm. in diameter.

The lecturer continued: The chief requirements of a moulding sand are refractoriness, permeability and cohesiveness. The first property is based chiefly on the chemical composition of the sand, the second on the grading, and the last on the nature of the bond.

Refractoriness.—Most sands are to a certain degree refractory, this property being regulated by the amount of silica which they contain. Silica softens at a temperature of about 1,600 deg. C. Refractoriness is not quite so important in sands for iron and brass as it for steel.

For steel moulding a material is required that will stand a temperature of about 1,700 deg. C.; hence the necessity for such substances as ground crucibles and powdered firebricks. Sands suitable for high temperature should be low in felspar, as this material fuses at a comparatively low temperature. All the sands which have proved successful for steel casting contain practically no felspar.

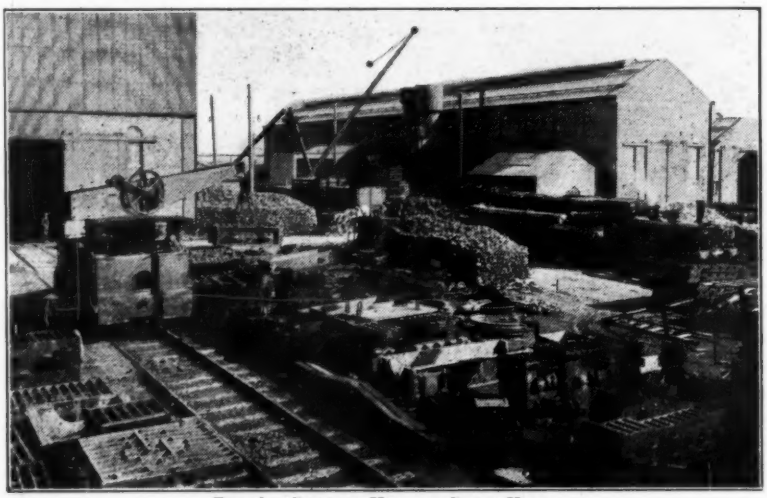


FIG. 4.—GENERAL VIEW OF STOCK YARD.

The best test for a sand is to subject it to a practical test, its suitability being judged by how it stands up to the work. Much information can be obtained from a chemical analysis of the sand; the geologist, however, can put a sand through a very severe test by examining it through the microscope, and in a very short time give its mineral composition and an opinion regarding its suitability for any particular work.

Permeability.—To secure this property a sand should be well graded, and the grade of a sand can very readily be determined by the microscope. Geologists find that the structure of practically all sandstones and the sections of moulds and cores are fairly similar. On examining the section of a core or mould through the microscope, it will be found that the larger particles of sand are connected by a film of the bond where they touch. The smaller grains, if any are present, fill up the inter-spaces between the larger grains and retard the escape of the gases generated at the time of casting; there-

fore, sand containing a large percentage of this finer material, such as silt, is objectionable. The grade of sand to be used for moulding depends upon the weight of the casting, heavy castings requiring a larger grade than a thin casting.

Cohesiveness.—The property of cohesiveness depends on the bond; sand obtains its binding properties from several sources, clay being the more common. Sands containing from 2 to 5 per cent. of oxide of iron are found very suitable for moulding purposes; in such sands the particles of sand are coated with this material. It is this oxide of iron that gives to a moulding sand its property of being able to lose and successfully take up again the moisture necessary to complete the bond.

The lecture was illustrated by a number of lantern views, and Mr. Tyrrell was accorded a hearty vote of thanks for his lecture.

SHEFFIELD BRANCH.

The Testing of Castings.

At a meeting of the Sheffield branch recently Mr. J. H. S. Dickenson, metallurgical expert to Vickers, Limited, read a paper on "The Testing of Castings." Dr. W. H. Hatfield, the President, was in the chair.

Mr. Dickenson's paper was as follows:—

The writer proposes to discuss mechanical testing in relation to the actual requirements of engineers, inquiring exactly what it is the engineer needs in his materials, and explaining how, by testing, he can be assured of getting it.

Mechanical testing is, of course, no new thing, since at all times since man first began to use materials he had been interested in their properties. Within the period in the evolution of mankind, whose history is written in the ruins of the East, we find progress in the more economical use and better employment of stone. Thus the early Egyptians built the columns of their temple so that the ratio of diameter to height was only five, the Greeks increased this to nine, and the Romans went still better.

Although such continuous improvement is evidence of testing—even if only by testing to destruction—there appears to have been no attempt made to measure those properties of iron and steel which appear important in relation to their application in structures and machines until 1722, when Reaumer devised several pieces of apparatus for directly testing the behaviour of metals under tension, torsion and bending, much on the same lines as have been followed in commercial testing to the present day.

It was not, however, until the coming of Bessemer steel in 1856 that it became the custom of civil users of material systematically to test their supplies, although for some special purposes, chiefly Governmental, there had been a certain amount of testing of both wrought and cast iron, and at Woolwich Arsenal iron, etc., was regularly tested long before this became the general practice throughout the country.

When, in the second half of the nineteenth century, cheap steel—first made by the Bessemer process, and later by the open-hearth—rapidly displaced wrought iron for ship-plates, boiler plates, rails and so on, engineers began to suffer from cases of unexpected brittleness, sometimes leading to serious accidents, and mechanical testing became the custom.

The methods of testing still commonly used in regard to most ordinary structural materials, and brought into use at that time, have as their special characteristic insistence on ductility. To secure this were specified a large minimum elongation per cent. in a tensile test piece, and, above all, a good bend test. The great dread of an engineer was brittleness, and to avoid this he limited his maximum stress, and, in addition to asking for a bend test to close up double, sometimes demanded this amount of ductility even after quenching out in water from a red heat.

When, as with rails and tyres, liability to wear called for harder material the drop test on a large scale was adopted for the same reason.

For a long time such tests served very well, even when applied to forgings such as crank axles, crank shafts, propeller shafts, and so on, for use in the older types of engine; for even if engineers by insisting on a high and altogether unnecessary amount of ductility obtained steel less liable to resist fatigue than they might otherwise have done, still in general rotating or moving parts were made so large that low tensile steels, with their corresponding low elastic limit and equivalent fatigue range, were amply strong enough for the purpose.

It does appear that the steel failures of the 'sixties, while inspiring the engineer with a wholesome horror of brittleness but with an undue regard for ductility, have since led to many fatigue failures in rotating shafting, etc., which our present knowledge teaches us how to avoid.

About the beginning of the present century a change came over engineering construction, particularly as regards motor engines, and the greater speed of rotation, with reduction in weight of moving parts, has not only compelled the engineer to revise his ideas as regards the testing of materials, but has brought into general use materials much harder than would have been considered safe only a few years ago.

New methods of testing have, therefore, been evolved to meet the altered conditions, some of value, others possessing neither scientific nor commercial interest, but none the less the trusted touchstones of those who use them. Testing is, in fact, becoming a complicated and yet as unscientific a business now as it was simple and unscientific in 1860; although the appropriateness of material for any specified application may be determined not only simply, but scientifically, if only the essential principles are kept in mind.

We find then that, so far as the engineer is concerned, the principal requirement of material is that it shall not fail in any way under stress, and I think the readiest way of approaching the matter is to consider first how steel may fail, and then to ask which physical properties are concerned and how mechanical testing may bring them to light. There are only two ways in which stress acting on a steel part can prejudicially affect it,* these being, first, by causing it harmfully to change shape, or, second, by causing it partially or completely to fracture. Bearing this in mind then, let us take the simplest form of mechanical test, the tensile test, when a measured test bar is pulled in two, and ascertain how much information this will give us.

On preparing a stress-strain diagram we find

* This paper leaves out of consideration questions relating to the corrosion of materials under stress.

that although different steels give different and characteristic curves, yet there is an essential similarity in a sequence of happenings. Leaving out of consideration matters which would only confuse the present issue, we find, first, that up to a certain point, known as the elastic limit, every added increment of stress causes a proportional extension, and that if the load is taken off the test piece returns to its original length, *i.e.*, the strain is elastic, and the steel is acting as a spring. A little above this point, however, the steel begins to stretch more than is justified by the load, and does not return completely to original length. Then, a little higher, the steel suddenly yields, stretching far more with a slight extra load than it has done with all the previous stress, and is now found on removal of the load to be permanently and considerably longer than previously. Having passed the yield point, as this is called, the steel continues rapidly to stretch plastically; it literally flows like a fluid, reaches a maximum stress, and then, forming a waist, finally breaks.

Much of the same sequence of movements takes place when a bar is supported on knife edges and is loaded in the middle, or when a cylindrical bar is held fixed at one end and is twisted at the other in the torsion test.

Reverting to the first type of failure mentioned, it will be seen that a member may fail if, by alteration of shape under stress within the elastic range, it fouls other portions of the mechanism or pulls them out of some desired position, as might, for example, happen in light framing carrying an engine or load. The only remedy then would be to thicken up that part, *since all steels are practically alike in their behaviour under stress up to their respective elastic limits.* Two bars of equal diameter and similarly supported, one of very mild and the other of very hard steel, would both bend precisely to the same extent, up to the elastic limit of the softer. In other words, all steels have about the same modulus of elasticity. They are all equally rigid, and *the only way to overcome whippiness is to increase scantlings.*

When, however, the failure of a structure results from a considerable and permanent deformation, as when a bracket bends down or a girder buckles, matters can be improved by using a harder material, and raising the elastic limit so that under the load which previously caused yielding, and a permanent collapse, it would now only bend elastically, recovering shape on removal of the load.

Although, for most practical purposes, the behaviour of the metal above the yield point would seem unimportant, since if either a shaft or a girder, as a whole, passed the yield point it would be useless, the amount of plastic flow which may take place up to the stress where fracture occurs has a value in certain eventualities. When stress is applied to a structure of irregular shape (and no structure, even the most uniform in outline, is ever quite free from some surface imperfections) concentration of stress may occur at some point or other, which may pass the yield point and reach the breaking stress, so that more or less complete fracture occurs, unless considerable local plastic flow, by distributing stress, relieves the situation. Failing this, the steel is too brittle, by absence of sufficient ductility, for its purpose.

Thus we learn from the simple tensile test (torsion and bend tests, although more complicated, giving much the same sort of information) the point above which material cannot be stressed without permanent deformation, the stress which when directly applied causes rupture, and also the extent to which it may be deformed between the elastic limit, and the stress at which final rupture occurs, *i.e.*, its degree of ductility.

Information regarding the physical properties concerned in cases of failure by deformation, and the simplest types of failure by fracture is, therefore, very readily obtained. There are, however, two other types of failure by fracture which require some consideration in order to understand the physical properties concerned.

Of these I will take first failure by fatigue, which includes the great majority of engine failures. We find cases where a spindle, a crank shaft, an axle—in fact, any part—subjected to stress during rotation or reversed motions, will behave perfectly well for a longer or shorter period, and then suddenly, and often without warning, break sharply off at some weak place where stress concentration may occur, for example, a keyway, an oilhole, or a fillet, giving a flat, smooth fracture, which suggests at first sight that the steel is brittle.

It was once generally supposed that such failures occurred from a general alteration of the steel as a whole, which originally stringy and tough, became under vibration or repeated stresses weak and brittle. This is now known to be erroneous, the fact being that on either side of the fracture the steel is absolutely unaltered. The mechanism of such failures has been clearly explained by the work of several investigators, notably that of Ewing and Humfrey in 1902, and I will deal with this as briefly as is consistent with clearness. It is necessary first to form a mental picture of what happens when a piece of steel, no matter of what kind, is stressed, and in doing this we must keep the stress strain diagram already discussed in mind. Now steel is a crystalline substance, the individual grains being exceedingly small (in all but abnormal cases), and always, except in the case of absolutely pure iron, of at least two kinds. The variations of structure which may be produced by heat-treatment, or alteration of composition, are enormous, and cannot be discussed here, so that, for the present purposes, it must be expected that any structural steel is made up, at the simplest, of two principal constituents, of which one, ferrite, or pure iron,* is soft, and the other, cementite, or carbide of iron,† is hard. It will be seen then, that if a bar of steel is stretched or crushed this can only happen by the corresponding alteration in shape of each individual grain. By microscopical and other means we find that each little grain is built up from the atom in an orderly manner, so that definite planes, called "cleavage" or "gliding" planes, are formed along which movement takes place when a crystal is plastically deformed by stress. The change of shape is like that occurring when a squad of men marching forward in fours is ordered to right (or left) incline, and not at all like the irregular movements of a crowd.

Now imagine that, at some severely stressed point on the surface of a rotating shaft, the crystals are being worked to and fro, now in tension, then in compression, by continued slip at

* Possibly containing other substances such as nickel in solution.
† Possibly a double carbide, as when chromium or tungsten are present.

certain gliding planes, and it appears that a certain amount of wear and tear is not unlikely. This, in fact, actually occurs, and after a time separation is effected at one or more of these planes, and a crack is formed which, once formed, is bound to continue growing until at last the shaft comes in two.

It is obvious that any test to determine the relative liability of different materials to fatigue must measure the range of stress from a maximum compression to a maximum tension, through which an infinite number of reversals may be made without causing such destructive slip in the crystals, and for this purpose a machine first used in the classic researches of Wohler, many years ago, is the simplest and not improbably the best. The effect of the work carried out with such machines is to show that materials have a definite limiting range of stress through which an infinite number of reversals may be made.

To do this properly by the Wohler method involves the testing of three (at least) distinct specimens from the same sample at different surface stresses, the results being plotted to give a curve from which may be deduced the stress range through which the specimen may be reversed for an infinite number of times.

It was suggested by Bauschinger and proved by Stanton and Bairstow that this limiting range coincides with the natural elastic range, so that to determine the true natural elastic limit would give the same information. In commercial testing, however, it is impossible to determine accurately either the limiting range of stress or the elastic limit, and it is usual to take the yield point in the tensile test (which in properly heat-treated material is not far above the true elastic limit and at all events gives a clue to its position) as a guide to the fatigue-resisting properties of material. It will be noted that neither the maximum stress nor the ductility are of any importance in relation to failure by fatigue.

We are left with only one further method of failure to examine, and that is when sudden failure occurs through brittleness in ductile material.

It is well known that ductile material may be made under suitable conditions to break in a brittle manner, two easy illustrations being those of sealing wax and pitch. A bar of either may be made to bend double if sufficient time is given, but will snap short if broken quickly. Now in much the same way it is found that there are some cases of steel which show great ductility in the tensile test or the ordinary bend test, but which are none the less liable, when subjected to shock, or even in some cases under steady stresses, to snap almost like cast iron. It is, therefore, necessary to devise some other testing method to determine the degree of "brittleness" or "fragility" in a sample and also clearly to bear in mind that "toughness" (the opposed property to "brittleness") is not at all the same thing as ductility, and that although in general material which has no ductility must also be brittle, yet it is quite possible that ductile material is also brittle under certain conditions of stressing. This being so, it is necessary when testing for brittleness, which I would define for the present purpose as "facility of crack propagation" to measure the energy required to effect fracture without permitting the test specimen as a whole to deform, since if this happens, as is possible with ductile material, the work of rupture is not determined for the original steel, but for the quite different and cold worked metal into which it has been transformed. Similarly, it is essential to apply the stress at a sufficient speed, which will differ to some extent with the material under test. The most convenient way so far evolved of effecting these objects is by breaking a notched test piece by the blow of a weight whose striking energy and velocity may be controlled, the residual energy after fracture of the test piece being measured by suitable apparaus. The Izod, Charpy and Fremont notched impact tests each obtain this result by somewhat varied means.

Just a word or two on the subject of testing cast iron. This material cannot be considered in the same way as steel, simply because instead of the constituent metallic crystalline grains being everywhere in close contact, and indeed bound together by a cement actually stronger than the crystals themselves, they are largely separated by plates of graphite having very small strength. As a consequence it is only under compression that this material gives really high values, its strength under any stress which tends to cause separation being very small. The tests applied in practice to cast iron are, as in the transverse test, merely directed to ascertain whether samples are up to some standard shown by experience to be reasonable and just; they do not attempt to give values for definite physical properties as is possible with homogeneous metals.

The same thing applies, though to a less extent, with malleable cast iron, any test piece of which is composite, and, indeed, to a very much less degree to steel castings. In the latter case the tests ordinarily applied have for objects first to ensure that the tensile strength is up to some desired level, but more particularly, by observing the elongation per cent. and the behaviour of a bend test, to ascertain whether annealing has been sufficiently effective.

Discussion.

THE CHAIRMAN, in opening the discussion, said the work of testing was of immense importance to foundry people, as every form of casting that was manufactured and would be manufactured in the future would have to satisfy a definite mechanical test. He thought Mr. Dickinson had brought home to them the absolute necessity of all their castings being free from defects of any kind.

CAPTAIN M. RUNDLE, R.N., said that the lecture had well demonstrated the great advantage of having these subjects illustrated on the screen. It showed how cracks in metals were developed, and gave them a clear indication of the value of micography in scientific investigations with metals. Before micography was used many of the deductions that were made were incorrect. By its help, however, they were able to see exactly what had happened.

MR. DAWSON asked if Mr. Dickinson had taken any tests of steel at 800 to 1,000 degrees. On the properties of steel at these temperatures would depend a good deal of the success or otherwise of their castings. He should like to ask if there was any relationship between the alternating stress test and the impact test.

MR. DARLEY asked what Mr. Dickinson thought of the drop test for intricate castings. His opinion was that the drop test was liable to set

up a fracture or weaken the casting, which gave out afterwards. Another point was with regard to the elongation test. He did not think they got any stress beyond 2 in. length. All the stress took place about an inch each side of the centre. Therefore it was not fair to expect about 25 per cent. in 8 in., as some people seemed to ask for.

Mr. Shaw said that he was sorry that the lecturer had not dealt more fully with the casting side. In regard to the tensile test, he thought it was about time they put forward some specifications for a definite size. Perhaps they as an Association might be able to do it. At present they had no standard size to work from, and they were all "at sea." He should like to ask if the tensile test was a good one for cast iron. He should not think it would be. In cast iron they had no homogeneous material. He had found there was no relationship between the tensile and the transverse test. He should also like to ask how far the impact test had been used for cast iron.

Mr. Charlesworth asked the lecturer if he could explain the reason for a chain, which in the ordinary way had been capable of lifting ten tons, breaking when it was lifting four.

Capt. Rundle said that his experience of testing was that the transverse test was the most reliable and the one to be most depended upon. He had always found a certain amount of uncertainty regarding the tensile test, but had found that the transverse test was good if the metal was good. He thought it would be helpful if Mr. Dickinson would show them any formula which would show the relationship between the two.

The Chairman said that he could not offer much hope for the cast iron foundry people in the tensile, transverse and impact tests. It had been found that cast iron was not sufficiently sensitive to allow them to discriminate between the different qualities when under test. Capt. Rundle had agreed with Mr. Shaw on the greater reliability of the transverse test as compared with the tensile test. There might be a simple explanation of this. It might be that the transverse test bar was 3 ft. long by 2 in. deep and 1 in. in width. These bars were frequently cast in sand. A perfectly homogeneous state was given to the bar. The disparity in the two tests was in one case they got a satisfactory metal to test and in the other they did not. He had done a lot of work on the subject, and found the tensile test extremely useful. When they came to malleable cast iron it was invaluable. The elastic yield and the maximum stress were practically the same thing. He did not think it was possible to fix an arbitrary test. If they cast iron in gradually ascending thicknesses they would find that the tensile went down as the test pieces became thicker.

Mr. Dickinson, replying, said that when he was asked to give a paper on testing he thought it was more desirable to know something about the principles of testing than to go into details about the testing of one particular branch in which a test was an arbitrary business. Capt. Rundle had spoken of micography in relation to testing. He thought it was all-important He was sometimes appalled in reading through the earlier researches to find how much importance was attached to formulas and calculations based on abstruse results. The underlying principles of testing could not be understood unless they looked into the integral parts and saw what was happening. He thought that to anybody who made a thing the properties of that thing must be of first-class importance. The work of the foundryman was not confined to making castings, but to the making of good castings. With regard to the relationship of the alternating stress test to the impact test, experiments had been undertaken recently, and it had been found that metals which gave an extremely good impact test gave a poor alternating test.

As regards the drop test for the intricate castings, what other test could they give? There had to be some sort of test.

Mr. Darley said that his point was that the vibration test was the best for the purpose. If there were any defects it would show them.

Mr. Dickinson said that it seemed to him that it was necessary to introduce some kind of test that would show unquestionably if a defect existed. The size and shape of a test piece was a purely arbitrary matter. The French had for years stuck out for a long test piece in proportion to the diameter. It was a matter of exchange of ideas. It could be adjusted. They would have to remember that both the transverse test and the tensile test were quite arbitrary. The results they got were very much dependent on the casting conditions. Discussing the matter of the chain which broke under a lighter load than the one it had been in the habit of lifting, he said those cases were very mysterious. The question of stress on a chain was not easy to work out owing to the varying angles at which loads were lifted. In one case a lighter load lifted at a peculiar angle might give a bigger stress than a heavier load at a different angle. The matter of the temperature of the castings was too big to tackle in a few sentences, and he would prefer to leave that matter to another occasion.

The offices of the Rugby Engineering Society have been removed from 9, Warwick Street, to 10, Elborow Street, Rugby.

THE AMERICAN FOUNDRYMEN'S ASSOCIATION.—At the annual meeting of the American Foundrymen's Association, to be held in Columbus, Ohio, October 4 to 8 inclusive, a new department will be added to the programme, to be known as the "Non-Ferrous Casting Section." At the meetings of this section papers and discussions of interest to the practical brass and aluminium foundrymen will be presented. It is understood that the Institute of Metals division of the American Institute of Mining and Metallurgical Engineers will hold a meeting in Columbus during the same week, and it is proposed to have a joint session of the Non-Ferrous Section of the American Foundrymen's Association and the Institute of Metals division of the A.I.M.E. This announcement will be of interest to the more than two thousand manufacturers of non-ferrous castings in the United States and Canada. Mr. C. S. Koch, president of the American Foundrymen's Association, has appointed Mr. Lucien W. Mueller, of the H. Mueller Manufacturing Company, Decatur, Ill., and Mr. Robert S. Archer, of the Aluminium Manufactures, Inc., Cleveland, Ohio, as members of the papers committee to represent this new section. The other sections that will be represented on the programme of the American Foundrymen's Association are the Grey Iron section, the Steel Foundry section, the Malleable Iron section, and the Industrial Relation section, and in conjunction with these meetings will be held the usual exhibit of foundry and machine shop tools, equipment and supplies.

Castings Used in Ship Construction.

BOLLARDS AND FAIRLEADS.

By Ben Shaw and James Edgar.

Bollards and fairleads are, as a class, smaller than the other castings which we have been considering in this series, but they are no less important, and present many difficulties to both the patternmaker and moulder. The variation in design is so great that it is not easy to choose those which satisfactorily illustrate all the principles involved in the construction of these articles.

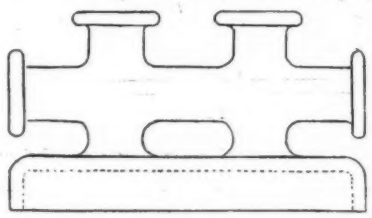


FIG. 1.

Figs. 1 and 2 show a very common type of bollard casting, in which the base is deep and cored out, but the bollards are solid. Sometimes these are cored out, but it is not the invariable practice. The pattern for this casting might be made in one of several ways, but whichever method is decided upon, the pattern should be jointed on the line AB, Fig. 2. One method of constructing the pattern would be to box up the base to the joint, and, after finishing the top part,

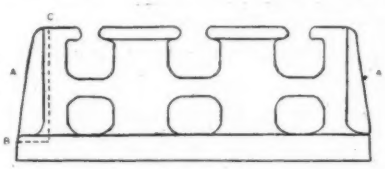


FIG. 3.

fasten the two portions together with long screws from the base into the bollards. The advantage of this is that it readily allows of alteration on some future occasion. A great disadvantage, however, is that this form of pattern is not sufficiently rigid, and it is so heavy that if roughly handled it may come in two parts.

The better plan is to make two half-lapped joints, as shown in Fig. 12, and build on them. The cross-pieces

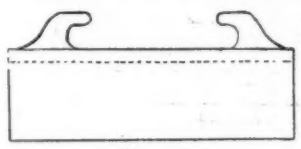


FIG. 6.

FIG. 5.

may be left sufficiently wide to allow of the fillets being cut out, but if wide timber is not available this is not actually necessary, as square corner blocks can be glued in, and the fillets cut after the bollards have been bunt on top of the plates. The boxed-up base is shown in the view of the finished pattern in Fig. 13. It should be made of fairly heavy timber, say, 1½ in. to 2 in. thick, and with even thicker ends, which allows the large radius to be taken off without weakening the pattern. As in all boxed pattern work, the top ought to slip inside and rest on a recess about ½ in. in width.

Some patternmakers would prefer to make the longitudinal bollard one long-lagged barrel from end to end, and joint short barrel pieces on to it for the cross or vertical bollards. This method is advisable in the absence of joint plates, but it does not make a really first-class pattern, in that all the fillets have either to be fitted round as segments and gouged in place, or left to the moulder. In Fig. 13 is seen a much better way. Solid square blocks, AA, Fig. 13, are planed up large enough to take the fillets. The diameter of the bollards, which may be anything from 6 in. to 12 in., is drawn on each of the faces, and they are neatly finished with a paring chisel and gouge. They should not be screwed on the joint frames until the pieces BB have been screwed to them. These pieces may be turned and the thickness of the joint-plate afterwards cut off at the "patternmaking" machine. When these combined pieces have been screwed to the joint-plates and also from the face of the base-piece, the barrel

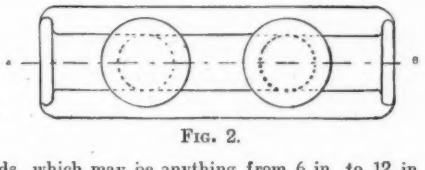


FIG. 2.

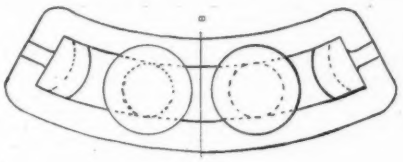


FIG. 4.

portions CCCCC may be made and put into position. Generally, if the diameter of these barrels is more than 8 in., it is well to use staves; below this diameter they can be made solid. The flanges on the faces of the bollards are easily turned. The prints on the base should be about 3 in. thick. When the base is being boxed up, thick pieces of timber should be fitted in opposite the position of the bollards, in order that the screw-holes can be bored through them. If this is not done difficulty will be encountered in inserting the screws, and they will not have the necessary holding power. The pieces need not be checked into the sides of the base, as they cannot move or be knocked out of position. They act also as grounds for the base. The small fillet behind the flanges can quite well be rubbed by the moulder. An ordinary framed core-box may be made for the base core, and the fillets here also can be ignored by the patternmaker. It is not often that a large number of castings are wanted from these pat-

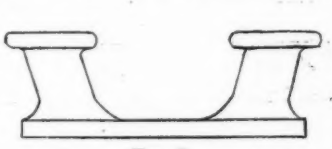


FIG. 7.

terns, or it would certainly be desirable to attach all fillets in the patternshop.

Fig. 3 is an elevation of a combined bollard and fairlead casting of rather awkward design. The plan may be straight or curved, as illustrated in Fig 4. This pattern, like the one we have already considered, is best built on joint-frames, but there are very important differences in the method of construction. Figs. 14 and 15 show a plan and elevation of a suitable frame for a straight pattern. A thick plate takes the place of a cored base, and instead of a bollard across the

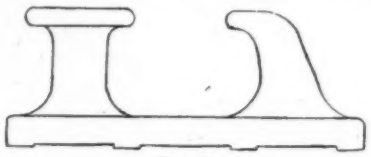


FIG. 8.

upright bollards there is a thick plate of metal between the two bollards, and also between the bollards and the fairleads. A flat frame would not be very rigid, because of the narrow widths of the centre plate of metal and the base flange, and therefore the frame shown in Figs. 14 and 15 consists of the finished flange; a centre-piece the width of the rib which is checked at the ends into the fairleads, and plates for the bollards and the fairleads. Fillets need not be taken into account in making the frame, and the fairleads are practically finished off before being screwed

FIG. 10.

into position. The bollard supports might be let into the flange and the centre plate to their full thickness, since when the barrel pieces are screwed into position they will form checks. The fairleads ought to be checked or shouldered as indicated by the dotted lines AB, Fig. 15. The ribs AA, Fig. 3, may be fitted against the fairlead and base flange without being checked in, but if they are fitted into a recess they cannot be rammed down, and they are a better support for the fairlead (see dotted line BC, Fig. 3). The flanges for the fairleads must be made by hand, and

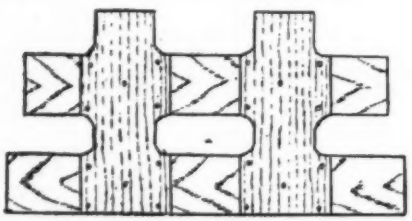


FIG. 12.

also the fillets, which may be fitted as thick segments, and gouged out afterwards. The bollard fillets are most quickly turned, and the easiest way of doing this is to screw the disc on the face-plate of the same thickness as the fillet radius, and of the same diameter as the bollards (A, Fig. 16). Segments can be fitted to this and screwed from the back of the face-plate, and then turned to a template. It is advisable to leave the edges about 1-16 in. thick, as otherwise they will break and look unsightly. Fillets like this can quite well be run off on a "Patternmaking" machine, the segments being left wider—that is, of smaller diameter on the inside—and band-sawn and sand-papered with a roller machine afterwards. Frequently the base is recessed, in which case the strip round the edge must be left loose, so that the moulder can draw it into the flange.

A circled design like Fig. 4 entails a little more labour than when it is straight. The pattern may be jointed in the same way, however, and joint frames made. These frames will, of course, be circular, and if the flanges are jointed on a straight line where the bollards are, it saves planing the bollard supports concave and convex. It is much easier to get such circled frames twisted than straight, and the precaution should be taken of screwing two circled guides to the floor, on which one frame can be built.

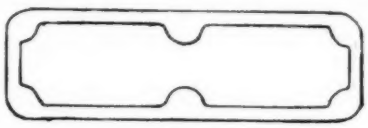


FIG. 9.

The most rigid pattern for a double bollard, as shown in Fig. 7, in which each bollard inclines at an angle, is made by checking bollard-joint plates across the flanges. The fillets in this case must be cut by hand. Fig. 17 shows the finished pattern with the fillets. It will be seen that lagged barrels are used. The grounds can, of course, be drawn geometrically.

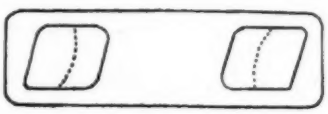


FIG. 11.

The type of fairlead which fits the shell of the ship (Figs. 5 and 6) is rather an expensive pattern to make. It must be jointed in the same way as the bollards, but the side-plate A, Fig. 6, has to be built in place. As this would be inconvenient, not only because of the difficulty the patternmaker would experience in doing the work outside, but because the patternwork would be held up until the plating was on the frames, what is termed a "mock" is usually constructed. This mock

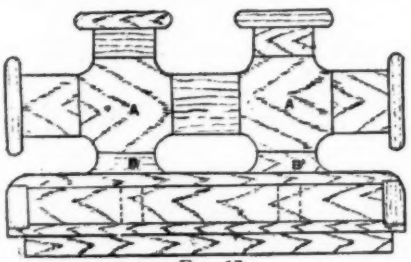


FIG. 13.

is a model of that part of the hull on which the fairlead rests. It is shown clearly at A, Fig. 20, and consists of two or more frames, on which ½ in. or ¾ in. timber is nailed. The reason for the use of this timber in the covering is to enable it to be nailed or screwed down to the frames, the edges of which will not lie on the same plane. The shape of the frames are, of course, obtained from the "scrieve" board, or the moulding loft. The top plate of the pattern, which should have cross battens let into it to prevent it from warping, should be first set in its correct position, and the side-plate built in thicknesses, as seen in both Figs.

20 and 22. Each piece should be thicknessed before being screwed in place. When finished, the pattern will appear like Figs. 21 and 22, the fairleads being built in layers. The corner block A, Fig. 22, is simply to strengthen the pattern, and has to be cored off.

Templates may be drawn from the prints for the core-box ends, or the box may be built round the print. The latter way is not good, as the core-box will probably be made a little larger than the print instead

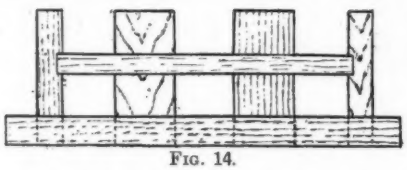


FIG. 14.

of a little smaller, as it ought to be. The moulder can strickle off the top with a straight-edge. Instead of the print, brackets are sometimes used, but they are not as convenient in the foundry. This double fairleads "hands," that is, different patterns are required for the port and starboard sides of the ship. The top plate could be used with the fairleads, and only a new side plate made. Of course, port and starboard mocks have to be made.

The flange, under which there is a fairly large fillet, is better built up. Although dowels are shown in the sketch, a spigot or male and female joint is better. The fairlead may be built of such thick timber as can be had, and it is good practice to joint the timber, so that there will be no tearing of the sides of the mould.

Figs. 10 and 11 are of a different type of casting. The base is rounded on the top, and the fairleads are at an angle (Fig. 11). The finished pattern is seen at Figs. 23 and 24, and each of these views show a different way of constructing the pattern. In Fig. 23 the

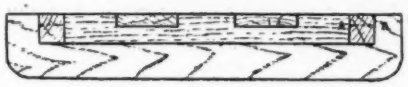


FIG. 15.

top portions of the fairleads are shown made separate and dowelled on, and this is certainly the superior way. Some foundrymen, however, insist on moulding them with the joint through the centre of the plate. If the pattern is made like Fig. 23 it is as well to make up the base with pieces for fairlead fillets and cut the convex top and the fillets at one operation. If the joint is made as in Fig. 24 the base plate or flange must be made quite independently, and then blocks

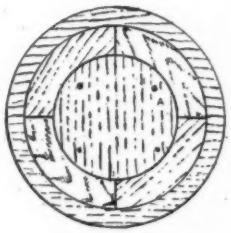


FIG. 16.

FIG. 17.

FIG. 18.

When building the job it is essential that the mock should be screwed to the floor, and the frames ought to be sufficiently thick to keep the mock reliable when the side plate is being fitted. It is also needless to say that no machining is left in the inner sides of the plates, and there must not be even a small fillet.

Fig. 8 represents a type of combined fairlead and bollard. It has usually fitting strips on the base similar to those that are shown in Fig. 8, or a face as

which have been glued up fitted and screwed to it. When the joints have been squared the fairleads can be drawn and then removed for finishing. They must not be glued to the base, as they will have to be loosened and drawn separately from the mould.

Although the patterns for bollards have to be strongly constructed, because of their weight, the thickness of metal is not quite as important as with many other castings. There must be no sharp corners,

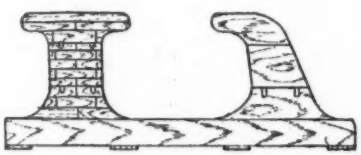


FIG. 19.

FIG. 20.

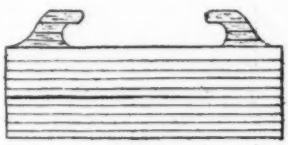


FIG. 21.

shown in Fig. 9. This pattern does not stand very high, and so, instead of jointing it longitudinally, the plates and the bottom fillet portion of both fairlead and bollard may be fastened permanently together, and the top portions dowelled. As the plate will probably be 3 or 4in. thick, and very wide, the method of inserting cross battens should be employed. Both bollard and fairlead may be quite finished before the fillet portions are screwed to the base plate. It will be observed that the bollard is shown segmentally built in the view of the finished pattern (Figs. 18 and 19) as an alternative method to fitting lagging on grounds. The only part that could be lagged is the middle.

and the hand or "touch" is almost as important as templates for finishing off the shapes.

Moulding.

Though not actually forming constructional castings, bollards and fairleads are essentially ship work. During the time of berthing or mooring a vessel, while it is being warped into position, the bollards and fairleads are subjected to considerable stress. Considerable reliance must therefore be placed upon them and much attention is given to the design to secure strength and rigidity. The heavy stresses to which they are subject—the bollards in particular—being

difficult to determine, and not infrequently, owing to the movements of the vessel in the water, applied suddenly, necessitate a factor of safety which is likely to cover abnormal conditions. The more expensive vessels for passenger or war service are usually furnished with steel castings for his work, whereas cargo vessels are provided with less costly iron castings. It is imperative that all parts with which ropes come into contact should be well rounded and free from any obstruction, hence they are riveted to the ship, attached by means of counter sunk bolts and the openings afterwards plugged. When the base is deep, as in the case of some bollards, they are bolted to the frame-

FIG. 22.

FIG. 23.

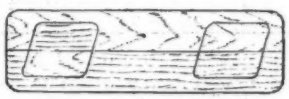


FIG. 24.

work through internal flanges, so that the upper space will be quite clear and smooth to allow easy running. The fairleads, which are mainly used as a guide for the ropes, either from the winch or to the bollards, are sometimes provided with a centre roller to limit friction, and to take up the wear on a part which is more easily replaced without removing the main casting.

Bollards are frequently hollowed out, though the metal is of substantial thickness, whereas fairleads are generally cast solid. The example shown in Fig. 1 is a type frequently used in the large class of vessels having a substantial base, and the whole lightened out to ensure a sounder casting. The mould is generally

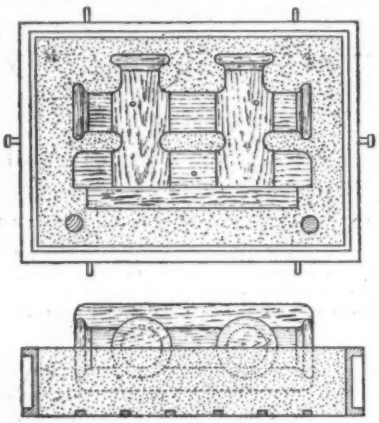


FIG. 25.—PREPARING THE DRAG BY THE ROLL-OVER PROCESS.

cast horizontally, with irons projecting from the ends of the core for support on the joint, in order to overcome the necessity for using chaplets or studs. When the roll-over method is adopted, and it is preferable if boxes are obtainable, half of the pattern is laid on a prepared bed, the drag-box set in position, facing-sand applied, and the whole rammed up and turned over as indicated in Fig. 25. The other half pattern is set, the position of gate-sticks determined, and the cope proceeded with. This method has a disadvantage when coring up, as the base core projects well above the joint of the mould, over which the cope must be lowered.

Many foundries prefer the bedding-in process for such jobs, with the joint carried below the surface of the floor, as shown in Fig. 26. This enables the moulder to make a joint at the top of the print for the base core, and then dropping it to the centre of the bollard and, equally as important, it allows the use of a simple form of cope box, having straight bars. Either grids or gaggers will take the lift, the former being preferable when they are well secured to the box. Substantial runners should be formed at each end of the base, and risers drawn off the upper surface, and from the ends of the bollard, leaving the working surface quite clear of runners or risers. This is advisable, in order to interfere with the regular contour as little as possible.

When bollards of this type are cored out, the reason is not so much to lighten the resulting casting as to eliminate the porosity of the metal, a failing which solid bollards possess. The accuracy of the diameter of the core is of little importance; a full height strickle board moved along a guide-plate to give the requisite contour will suffice to so shape the loam that it can be easily ribbed circular in section after it has been dried. To stiffen the core a single barred grid is sufficient, and, since it is preferable to pour such castings on the flat, it is advantageous to carry the core iron through the mould, in order to obtain support for the core. When a base core is necessary, as in this instance, impressions are made by prints in the core-box for locating the lightening core, and the two cores can be secured by having eye bolts cast in the lightening core grid, as shown in Fig. 27. These are long

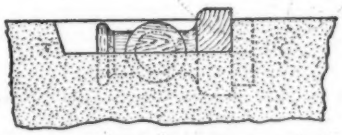


FIG. 26.—BEDDING IN THE FOUNDRY FLOOR.

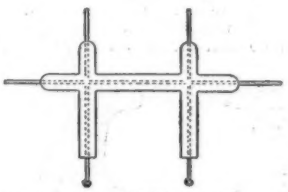


FIG. 27.—A SUITABLE LIGHTENING CORE.

enough to pass through the base core, to which they are easily secured. An illustration of the mould preparatory to closing is shown in Fig. 28. Usually the metal forming the base is thick enough to allow runners being formed at the side of the core as indicated, but sometimes the metal is applied to either one or both ends, and in a line with the main plate of the base from which the bollards project. The moulds for the larger kind of bollards are generally dried and blacked over. Some are made in green sand, and in this case special attention must be given to the facing mixture. The dry-sand method is the better practice, not only because the method provides a better skin to the casting, but there is no risk of a draw on the cope, due to the heat, as in the case of the green-sand mould.

The combined bollard and fairleads shown in Figs. 27 and 28, having a curved base, are sometimes moulded horizontally with the major part of the drag formed in the foundry floor, as indicated in Fig. 29. Such a method requires less tackle, and usually less time is occupied in preparing the mould, and providing a lightening core is required for the bollards or denseners are cast in with the job, it is preferable. If the bollards are to be solid, and no denseners are used, then casting in a vertical direction is by far the best, since it offers better facilities for substantial risers.

The fairlead shown in Figs. 5 and 6, besides fitting on the deck, is made to take the contour of a part of the side of the vessel, and considerable care must be exercised in the foundry to maintain the true shape of

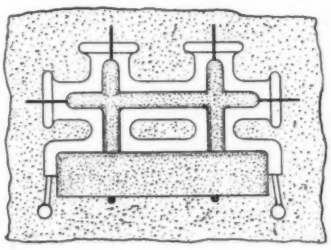


FIG. 28.—PREPARATORY TO CLOSING.

the pattern, and so limit the time required to fit the casting into its position. This type of fairlead limits the moulder in his choice of method in preparing the mould. The side plate must either be moulded in the top or bottom. Usually, when the angle it forms with the base is less than a right angle, as in this instance, the better plan is to cast with the plate uppermost; risers can be more conveniently placed when this method is adopted. It is common practice to maintain the correct shape of the pattern by means of brackets or blocks during the time of ramming up, but these need not necessarily be left on all the time. The half

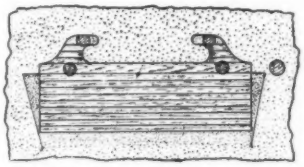


FIG. 31.—READY FOR COVERING.

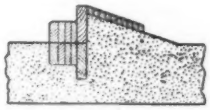


FIG. 32.—SECTION OF DRAG.

pattern carrying the side-piece can be bedded into the foundry floor as shown in Fig. 30, using it as an odd-side or false part. After it has been bedded in in this way, the joint continuing the inside shape of the plate, and the ends well tapered back, the supporting ribs or blocks can be removed, the other pattern section set, and the drag-box located for ramming up. Since the drag part is required to be rolled over in order to form the cope, it is better to carry the lift by means of a grid firmly secured to the box-part so that some cinders can be used to vent under the plate. Fig. 31 gives a plan of the drag rolled over and the pattern section replaced preparatory to commencing the cope, a section being shown in Fig. 32. A single runner at the end of the main base is sufficient to supply the metal, and risers placed as shown in Fig. 31 are helpful in finishing the thicker parts of the casting without interfering with the uniformity of the working parts. When the foundry floor is used for the drag, greater difficulty is experienced in regulating the density of sand about the side-plate, and there is considerable danger of the resulting casting not being true to pattern.

The fairlead shown in Figs. 10 and 11 is made in a vertical direction either by means of a three-part box, or by having part of the impression in the foundry floor. The base is usually made uppermost for convenience. Metal is best supplied by way of one end of the base and two risers brought off directly above

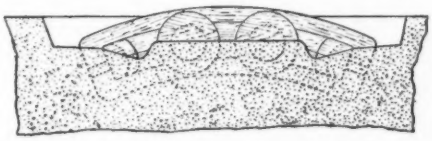


FIG. 29.—THE FORMATION OF JOINT WHEN MOULDED HORIZONTALLY.

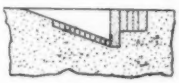


FIG. 30.—MAKING AN ODD SIZE.

the leads, and the metal should be well fed after it has been cast.

The somewhat common type of bollard illustrated in Fig. 7 having the heads at an angle with the base, which are frequently lightened out in the case of steel castings, is moulded horizontally, the joint corresponding with the joint of the pattern. The better plan is to use a two-part box, ramming the drag part over the bottom section of the pattern, which is laid on a prepared bed. When special boxes are stocked, or when

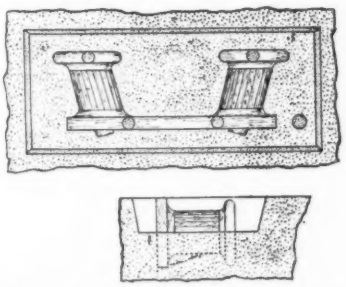


FIG. 33.—MOULDING HORIZONTALLY WITH JOINT DROPPED BEHIND FLOOR LINE.

loose box bars can be fixed in the box parts, this method undoubtedly possesses advantages for securing a good impression, and is to be recommended. With the exception of those foundries which specialise in this class of work it is not economical to provide special tackle for what may be only one-off jobs, hence the ordinary tackle stocked is utilised. Usually, under these conditions the broken section of the pattern is bedded into the foundry floor and the joint dropped below the floor level, sufficient to allow the use of a cope box having ordinary straight bars cast in. This type of pattern is not difficult to bed in, as, with the exception of the edge of the boss, all parts are

accessible for ramming. The adoption of such a method increases the top lift considerably and necessitates the use of a large number of gaggers, or, better still, grids, if they can be secured to the box bars conveniently, to give the requisite strength to the cope. The joint to the floor level should be well tapered back and a good parting made. Sleeking over with sea sand is very useful in such instances. A plan and section of the pattern having the bottom rammed joint made and ready for the preparation of the cope is shown in Fig. 33. One runner conveying the metal to one end will suffice, and risers can be drawn off where indicated in the sketch.

After the cope has been rammed up, screw eyes

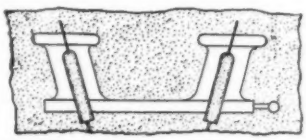


FIG. 34.—METHOD OF SETTING CORES.

should be fixed into the top section of the pattern, and temporarily screwed to the box as a precaution against it falling when lifting.

When the pattern has been withdrawn and the mould cleaned up, dried, blacked, and then thoroughly dried again, the lightening cores can be set in, as indicated in Fig. 34. The cope is then lowered into position and preparation made for casting the metal.

The combined bollard and fairlead, Fig. 8, is usually cast solid, and in order to get the metal as dense as possible the flange or base is generally cast uppermost. This enables the moulder to draw substantial risers off both bollard and fairlead, by which they can be fed. Many foundries make use of the foundry floor for part of the impression, making up the first joint as shown in Fig. 35, arranging the depth from the joint to the base of the pattern to correspond as nearly as possible with an available box part. The great difficulty experienced in this method is in locating the parts which are bedded into the floor. These are loose, and as they are difficult to secure temporarily, they are likely to be rammed out of position. A more efficient method of preparing such a mould is illustrated in Fig. 36. In this instance the base is set on a prepared bed and a middle box part rammed up to the

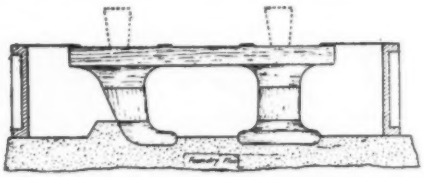


FIG. 35.—PREPARING THE MOULD VERTICALLY, THE FOUNDRY FLOOR TAKING PART OF THE IMPRESSION.

first joint. The loose pieces can be more conveniently held in position in this way.

After the joint has been made and the drag box rammed up, the two parts require to be well secured together and then rolled over for the top box. Generally all bollards made solid are preferably cast with the base flange uppermost, and in many cases an iron core or densener is suspended in the mould, which becomes part of the resulting casting.

Conclusion.

These series of articles indicate the more general practice adopted in obtaining the moulds with which sound "ship castings" may be obtained. The authors recognise that differences of opinion exist amongst foundrymen respecting the best procedure for the varying types of work; different countries have different methods in applying the principles involved in securing sound castings, and it is rarely indeed that any two foundries adopt exactly similar methods. No one foundry can be said to possess the best ideas for turning out all kinds of castings, sound and economically.

One of the best means of bringing about uniformity in the preparation of moulds is by describing the methods adopted through the medium of the Technical Press. The literature relating to the production of large steel castings, particularly for ship purposes, is extremely scanty, and the circulation of methods which have proved successful influence the average foundryman and tend to increase production.

Many factors must be taken into consideration with regard to the construction of the patterns; some foundries having plant and tackle suitable for patterns which more nearly represent the finished casting, while others prepare special core floors to reduce the moulding space in order to cope with block patterns having separate cores. The system of payment may influence the foundry executive in preferring the latter method of dividing the work and increasing the amount of labour on any given job to secure more rapid production. Then it is usual for the patternshop to prepare the patterns according to the system adopted by the foundry likely to undertake the work. Good patterns

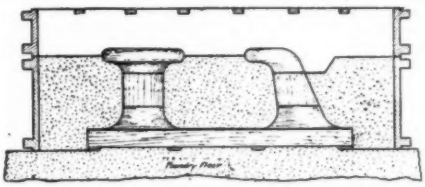


FIG. 36.—THE METHOD WHEN USING A THREE-PART BOX.

are essential to the steel founder, as the nature of the composite forming the face of the mould does not allow for that same degree of patching up such as is employed in moulds for cast-iron.

Quite apart from the fact that steel moulders require a good pattern, the nature of the casting, especially in connection with those for ship construction, make it imperative that a strong pattern be supplied having that rigidity likely to produce a true casting.

While these articles have been mainly concerned in the construction of typical patterns and the preparation of their moulds, the character and composition of the sand used and the temperature and quality of the metal when poured are of equal importance in the production of sound castings. Given a good "compo" possessing the necessary cohesiveness and sufficiently refractory to withstand the high temperature of the metal, the technical skill required in devising the best means of preparing the mould so that shrinkage and contraction difficulties are reduced to a minimum, has much to do with the success of the resulting casting.

Many castings are lost through lack of caution when annealing, whether the casting to be annealed is packed in the furnace hot or cold, the temperature of the furnace should be approximately near to that of the work, and care must be exercised in packing to give the necessary support to the casting without interfering with its free movement as the temperature is increased or reduced. The furnace should be heated up very gradually, the temperature and the duration of the heat depending largely upon the character of the work, and just as it is necessary to raise the temperature gradually, it is, if anything, more essential that it should be reduced gradually.

The Influence of Cadmium on the Properties of Brass.*

By Leon Guillet.

Our knowledge of the influence of cadmium on the properties of the brasses is extremely limited, and to complete this grave deficiency the author undertook the systematic investigation of these alloys about the end of 1918.

The method followed was that utilised in the previous researches by the author, and three series of alloys were prepared as follows:—

(1) A series of 70 per cent. copper alloys.

(2) A series of 60 per cent. copper alloys.

(3) Several alloys in the neighbourhood of 55 per cent. copper.

The last series purposely contained high percentages of cadmium.

Results of the tests on the first series of brasses containing 70 per cent. copper:—All the mechanical tests performed on the various series were made under the following conditions. Tensile test specimens 13.8 mms. in diam. and 100 mms. between the gauge points were used. Shock test specimens 10 by 10 mms., with a notch of 1 by 1 round at the base were broken on a rotary tup machine. The hardness tests were made with a 10 mm. diam. ball under a load of 1,000 kilograms.

Table 1 gives the results obtained on the brasses of the first series.

These results show that up to 0.74 per cent. cadmium none of the properties of the alloy are modified, and at 1.67 per cent. of this element a slight reduction in the tenacity commences. The resilience is also lowered, and the hardness undergoes a slight increase. This continues until, with 4.11 per cent. of cadmium the tenacity is lowered to an insignificant value, and the ductility is nil. The resilience reaches a very low figure, and the hardness the highest value of the series.

Table 1.

Composition.			Tensile test.			Shock test.		Hardness.	
Cu. per cent.	Zn. per cent.	Cd. per cent.	U.S. Kgms.	Elong. per cent.	R.A. per cent.	Energy. Kgmmetres.	Bend.	Diam.	No.
69.96	30.07	Nil	20.0	49	,,	17	,,	5.30	47
69.80	29.93	0.17	21.5	63	,,	16.8	,,	5.40	45
69.69	30.03	0.24	21.5	57	,,	17.5	,,	5.35	46
69.94	29.40	0.49	19.9	45	,,	16.8	,,	5.40	45
70.11	29.07	0.74	20.4	47	,,	18.0	,,	5.20	48
69.83	28.37	1.67	19.2	33	,,	6.3	128	4.95	54
70.02	27.94	1.92	9.5	7	14.2	6.3	125	5.15	50
70.87	—	4.11	3.6	—	—	1.9	—	4.65	61

Table 2.

59.73	40.26	Nil	34.4	40	42.2	12.5	115	4.25	75
59.51	40.16	0.15	33.8	38	37.7	12.8	120	4.15	78
60.18	39.25	0.40	33.5	48	49.7	13.1	115	4.20	77
59.99	39.34	0.54	34.3	39	48.6	15.6	105	4.10	80
60.18	38.72	1.07	34.3	32	31.9	9.4	135	4.10	80
60.11	38.15	1.67	34.0	28	31.3	5.9	150	4.00	84
59.61	38.18	1.97	33.5	19	18.2	4.3	165	3.90	89
60.05	34.87	4.54	24.1	9	7.3	3.1	175	3.85	92

Table 3.

55.20	44.75	Nil	39.0	20	30.7	13.1	132	3.25	130
55.80	42.38	1.82	32.1	5	12.8	3.1	173	3.25	130
56.37	39.46	3.64	32.2	6.5	8.7	2.8	175	3.45	115
54.44	38.03	7.26	13.4	0.5	1.4	1.3	178	3.30	126
55.35	34.95	9.22	12.1	0.5	114	1.3	178	3.20	135

A microscopic examination was made, and it was found that up to 0.74 per cent. cadmium the alloy had the normal α solution structure. The alloy containing 1.67 per cent. cadmium shows traces of free cadmium with increasing quantities of this element appears in the free state.

Results of tests on second series of brasses containing 60 per cent. copper:—These tests were made under the same conditions as the previous series, and the results are shown in the following table (Table 2). In this case the mechanical properties do not suffer any change with quantities of cadmium up to 0.54 per cent. With a percentage

* "Revue de Metallurgie," Nov.-Dec., No. 6.

of 1.07, a slight lowering of the elongation and the reduction of area, and also a diminution in the resilience value is noted. With increasing quantities of cadmium the tenacity remains constant up to a percentage in the neighbourhood of 2, but the elongation and reduction area are lowered as is also the resilience. The micro study shows that the diminution in the value of the different mechanical properties coincides with the appearance of free cadmium in the structure. The results obtained from the tests taken on the third series of alloys containing 55 per cent. of copper are given in Table 3. Again, in this series the ultimate strength is not affected until comparatively large quantities of cadmium are present. The elongation, reduction of area, and resilience are altered very rapidly. The presence of cadmium in the free state renders the calculation of the equivalence coefficient of this element somewhat difficult. Neglecting the traces of free cadmium the following formula can be applied, in which:—

A is the real value,

A′ the fictitious value as determined by the microscopic observation.

q the quantity of the body desired to be determined.

In this case the value $t = 1 + \frac{100(A-A')}{A'q}$ This value is only approximate.

Conclusions:—

(1) The presence of 1 per cent. of cadmium in brasses containing 60 and 70 per cent. of copper can be admitted without having to fear any serious modification in the mechanical properties.

(2) The influence of cadmium makes itself felt for the most part in its action on the resilience. This falls more rapidly than the other properties.

(3) The modifications in the mechanical properties brought about by the introduction of cadmium correspond to the appearance of free cadmium in the microstructure. This exists in threads which have a tendency to surround the grains of the metal when the percentage becomes higher the cadmium tends to form spherical agglomerations recalling those of lead in brasses.

(4) The cadmium retained in solution by the constituents of the brasses has a coefficient of equivalence of $t = 0.7$.

(6) It would appear that manufacturers and also users of brasses had considerable doubts concerning the influence of cadmium. In quantities of 1 per cent.. a percentage which is rarely attained in commercial alloys, cadmium has no harmful influence on the mechanical properties.

Heat-Treatment of Carbon Steel.

At a recent meeting of the Birmingham Metallurgical Society a Paper was read by Mr. H. I. Coe, M.Sc. (Head of the Department of Metallurgy at the Technical College, Swansea) on "The Heat Treatment of Medium-Carbon Steel." After describing the changes undergone by the steel as the temperature was increased, Mr. Coe said that it was usual to carry out hardening operations from a temperature about 50 deg. C. above the end of the change point, so that reasonable latitude was allowed for most general purposes. The steel underwent similar changes, though in the reverse order, upon subsequent slow cooling, but the change points occurred at considerably lower temperatures. Advantage might occasionally be taken of this difference in order to reduce the temperature from which hardening was carried out, and so reduce the danger of cracking and warping. The presence of a small quantity of manganese appeared to decrease the freedom of movement of the molecules in solid solution, and probably for this reason tended to hinder the attainment of a state of solid solution throughout the steel at the hardening temperature, so that a longer exposure to that temperature would be required. In a normalised or annealed steel, the effect of manganese in producing a finely laminated or sorbitic pearlite was very clear. The irregularity in the distribution of the phosphorus in steel which had not been thoroughly annealed was accompanied by a lack of uniformity in the distribution of the carbon, portions rich in phosphorus being low in carbon, and *vice versa*. In the rolled material, layers of relatively hard and strong material were found sandwiched between layers of relatively soft and weak material. When such material was hardened by quenching from above the critical ranges the difference in properties was magnified. The hardening temperature which was correct for the carbon-rich phosphorus-poor portions was low for the portions relatively poor in carbon and rich in phosphorus, and, in consequence, particles of free ferrite might be found in those portions. The difference in hardness thus became greater. A material possessing a banded structure due to irregular distribution of the phosphorus would not have the best possible general properties. Very drastic annealing was required to ensure complete diffusion of carbon and phosphorus throughout the steels.

Dealing with the general question of heat treatment, Mr. Coe said that the best combination of ductility with tensile strength was produced by oil-hardening from 850 deg. C. followed by tempering. The results of his experiments were in agreement with the view generally held that the best hardening temperature was one not far removed above the temperature at which the state of complete solid solution existed in the steel. Judging from Law's experiments, water had many obvious advantages as a quenching medium, and might be successfully used in the hardening of large forgings of the lower-carbon steels, which, on account of their toughness, would be less liable to the formation of hardening cracks. The Vickers surface-hardening process was specially adapted to the hardening of relatively small surfaces on large articles, but rapid heating was essential for success. In all partial hardening an abrupt transition from hard to soft material was to be deprecated, as failure would very readily occur at the junctions of the two parts if even a small stress was applied in the right direction.

In the course of the discussion, the President (Mr. F. C. A. H. Lantaberry), speaking with regard to phosphorus, said there was a general consensus of opinion that phosphorus could not be caused to diffuse uniformly through a piece of steel by any ordinary process of annealing. If it were possible to diffuse the phosphorus through the steel then they would not get the phosphorus bands. The advantage of alloyed steels was that whilst carbon steel and alloyed steel might be treated to give the same static properties, they possessed very different dynamic properties.

Mr. Hayes said that quenching in hot water had been found to prevent splitting.

Mr. Davis said he had seen the Vickers surface-hardening process in operation. Two jets were used, one providing an oxy-acetylene flame and the other a jet of water, and the two jets were moved slowly along the parts to be hardened so that the water immediately followed the heating and caused definite water-hardening.

Mr. Coe, in his reply, said that he had noticed that the phosphorus bands were most pronounced in steels with a low-carbon content. He understood from Dr. Stead's work that under critical conditions, which would not be economical, these bands could be removed. But he took it to be probable that even the most drastic annealing would not entirely eliminate

them. He thought the phosphorus bands could be clearly distinguished from rolled ferrite banding free from phosphorus in steel by fairly deep etching. The band structure, he believed, was fairly frequent in steels in which the phosphorus was unimportant; for instance, nickel chromium steel. He agreed upon the importance of soaking at high temperatures. The time of soaking should be measured by hours. The steel employed in his experiments was an acid steel, and the sections were taken from rings of large gun forgings.

Rust-Proofing Iron and Steel.

Details of the Use and Application of Phosphatic Coatings.

By L. E. Eckelmann.

In a recent issue of the "Chemical and Metallurgical Engineering," Mr. Eckelmann discusses the employment of phosphatic coatings to iron and steel.

Recent phosphatic rust proofing differs from other methods in that the dimensions or sharpness of finely machined edges and surfaces of the articles are not appreciably altered. Due to the low temperatures used, the physical properties of tempered steel are in no way affected, and magnets so treated retain their magnetic force. Even very fine springs do not have their elasticity impaired. The remarkable adhesion or molecular bonding of the phosphatic coatings is shown by the fact that even under very severe conditions of deformation, the coating does not split off. On the other hand, dental needles having points so fine (0.003 in.) that a slight corrosion ruins them completely are successfully protected by phosphatic coatings without injuring the elasticity of the needles or affecting the delicate barbs covering their surfaces.

Coslett's Process.

Rust proofing is effected simply by immersion of the clean objects in a hot solution for periods of one to three hours. The deposition of the coating depends upon the action of a solution of iron phosphates in weak H_3PO_4 on a metallic base, such as iron. Phosphoric acid solutions will dissolve ferrous phosphate within certain limits in direct proportion to the concentration of the acid present. If any base or metal be added—for example, iron—capable of entering into combination with the free acid present in such a solution, the formation of ferrous phosphate on the metallic surfaces will precipitate this salt back on the iron at the point of solution. The already saturated condition of the iron phosphate solution will naturally aid the precipitation when more of this compound is formed. The action proceeds with the evolution of hydrogen until no more elemental iron is exposed, the article being then completely coated with a basic iron phosphate.

This reaction was the basis of the process developed by Coslett in 1907, its later commercial adaptation operating as follows:—Ferrous phosphate made by mixing iron filings with concentrated H_3PO_4 sufficient to form a semi-fluid paste was added to weak boiling phosphoric acid. Iron or steel articles were immersed in this boiling solution for three or four hours, and when removed were covered with a rust-resisting light grey deposit of basic ferrous phosphate. The difficulty of obtaining uniform coatings, the great amount of suspended salt adhering to the work—in some cases incorporating itself with the actual coating and increasing the dimensions of the articles—the consequent necessity of rinsing the work after treatment, and the non-uniformity of the finish, all contributed to the slow adaptation of this process until these troublesome features could be eliminated.

Parkerising.

Messrs. Allen and Richards were mainly responsible for changes in the Coslett process, which made its present modification one of the most simple methods of rust prevention. Their patented modification in use to-day is known as "Parkerising." The old Coslett solution was modified by the addition of an oxidising agent such as MnO_2 to a 0.75 per cent. solution of H_3PO_4 containing ferrous phosphate, this salt being partly oxidised to the ferric state after continued agitation and boiling. This last action is necessary to complete the partial oxidation of the ferrous salt, the correct proportion between the phosphates being 3 ferrous to 1 ferric. The formation of the coating, a basic ferroso-ferric phosphate, is similar in action to the Coslett reaction mentioned above. It has been found lately that part of the MnO_2 may be replaced by air, also that in the latter case the action of the MnO_2 can be considered as partly catalytic.[1] In the latter method of oxidation, the method of aëration presents a practical problem, since the finish of the work will be affected if the objects processed are of complicated form, and air be trapped and held in contact at any point.

Chemical Control.

Ten cc. of the rust-proofing solution should be equivalent to 14.5 cc. N/10 NaOH for good results. Acidity running up to 18 cc. N/10 NaOH is not harmful, but higher amounts will have a pickling action on the work.

Twenty-five cc. of the solution should contain from 0.0236 to 0.0335 g. ferrous iron, and from 0.0019 to 0.00559 ferric iron. This is titrated with N/10 $KMnO_4$ in the usual manner—for more accurate readings N/20 $KMnO_4$ should be used. Correct correlation of acidity, ferrous and ferric iron is essential, and must be closely watched and controlled.

For convenience in operation, the acidity of the rust-proofing bath is expressed in "points of strength," 1 cc. N/10 NaOH being taken as one point. The depletion of the solution after each batch of work is coated will vary slightly from one to two and one-half "points." Acid and MnO_2 are added, the amounts and proportions per gallon given above being equivalent to one point of strength.

Results of Phosphatising.

Objects of iron and steel treated by the above process are very resistant to rust, withstanding exposure, saline atmospheres or laboratory fumes to a large degree, and testing very satisfactorily under the salt spray.[2] (See Fig. 4.)

Iron and steel protected with phosphatic coatings are not so resistant to wear and abuse as sherardised or galvanised metal. Surfacings composed mainly of Fe_3O_4 produced by the Bower-Barff and similar processes are more resistant to acids and bluer in colour. However, phosphatic rust proofing is considerably cheaper than any other well-known rust-proofing process in use to-day, the simplicity of treatment and uniformity being important factors in its favour.

COAL METER FOR CHAIN-GRATE STOKERS.—A new coal meter is made by the Lea Recorder Company (Manchester) for boilers fitted with chain grates. The meter depends upon the theory that the amount of coal passing under the fire door of a chain-grate stoker may be regarded as a stream of constant width but variable depth and velocity. Also, the weight of a given volume of coal is nearly independent of the size of the pieces. The counting wheel allows for both variables (depth and speed of fuel flow), and its unit may be determined experimentally for the particular fuel employed.

[1] See U. S. Pat. No. 1,248,053.
[2] General Electric Bulletin, No. 48.926.

A Rapid Method for the Analysis of Monel Metal.

By PHILIP COVITZ.

The author, writing in "Chemical and Metallurgical Engineering," describes a complete method of analysis. This will be of interest to many of our readers, and fuller details regarding the preparation of solutions are to be found in the original.

By combining various well-known rapid volumetric and gravimetric methods, an important saving of time without sacrificing accuracy is assured in analysing monel metal, an approximate average percentage composition of which is:

Cu, 20 to 30; Ni, 60 to 70; Fe, 0 to 3.5; Al, 0 to 0.5; Mn, 0 to 3.5; C + Si, 0 to 0.8.

The usual procedure has been to dissolve a weighed quantity of the alloy (usually 1 gram) in nitric acid, filter off the silica and carbon, electrolyze the filtrate for copper, remove iron, aluminium and manganese by brominising the ammoniacal electrolysed solution, re-dissolve the precipitate and separate the elements; and finally determine nickel by the glyoxime method in the filtrate from the various precipitations. Carbon was obtained in a separate sample.

Determination of Silicon.

Weigh 1 g. of monel shavings into 200 cc. beaker, add 10 cc. HNO_3 (1.42), heat until dissolved and evaporate to approximately 7 cc. Dilute to 50 cc. with hot H_2O, filter through No. 42 Whatman 12.5 cm. paper into 300 cc. beaker. Wash thoroughly with hot H_2O, keeping volume of filtrate below 150 cc. Ignite and weigh SiO_2. If precipitate is heavy and discoloured treat with HF and determine loss.

Per cent. $Si = 46.9 \times SiO_2$ ppte.

This method is open to criticism in that the silica is not dehydrated. In the opinion of the writer dehydration in most cases for silicon in monel metals is unnecessary. If the analyst should prefer it, however, the following procedure should be adopted:—

Weigh 1 or 2 g. of borings in porcelain dish, add 10 cc. HNO_3 (conc.) and 5 cc. H_2SO_4 (conc.), evaporate cautiously to dryness, and heat until H_2SO_4 fumes freely. Cool, dissolve in 10 cc. conc. HCl, dilute to 50 cc. with hot H_2O, filter, wash with hot 1 to 1 HCl and hot H_2O, dry, ignite in muffle and weigh SiO_2. Do not use this filtrate for electrolysis.

Copper.

Cool filtrate from SiO_2, make up to 150 cc., and add 5 cc. 1 to 1 H_2SO_4. Electrolyse, using a current of 1.5 amp. for 2 hours. Rinse electrodes, wash with C_2H_5OH, dry one minute in oven at 110 deg. C. and weigh deposited copper.

Iron and Alluminium

Weigh 1 g. of borings into 500 cc. beaker, add 10 cc. HNO_3, heat until dissolved, and dilute to 250 cc. with hot H_2O. Add 5 g. NH_4Cl, make ammoniacal, and boil 5 to 10 minutes. Allow precipitate to settle and filter through No. 40 Whatman paper (12.5 cm.). Wash thoroughly with hot H_2O. Reject filtrate. Transfer bulk of precipitate back to original beaker, pour hot 1 : 1 HCl through filter, and catch solution in this beaker. Wash paper free from iron. Warm beaker gently (do not boil). When precipitate has dissolved dilute to 250 cc. with hot H_2O, add 3 g. NH_4Cl and NH_4OH in excess. Boil 5 to 10 minutes, allow precipitate to settle and filter through No. 40 paper. Wash thoroughly with hot H_2O. Discard filtrate. Again dissolve precipitate as before, using as little HCl as possible, and wash filter thoroughly. Heat gently until iron is dissolved and add slight excess of 50 per cent. KOH. Dilute to 150 cc. and boil 5 to 10 minutes. Let settle, filter through No. 40 and wash thoroughly with boiling H_2O. Save filtrate.

Iron.

Place paper containing precipitate of $Fe(OH)_3$ into original beaker, add 10 to 15 cc. HCl and warm gently until precipitate dissolves. Add from dropper $SnCl_2$ solution drop by drop until decolorised, and then add 10 cc. $HgCl_2$ solution. Wash into 800 cc. beaker containing 400 cc. cold H_2O and 20 cc. preventive solution. Dilute to 600 cc. and titrate immediately with 0.03N $KMnO_4$ to end point which remains one minute. Conduct blank titration using same quantities of reagents.

Preventive solution: dissolve 160 g. $MnSO_4$ in H_2O, dilute to 1750 cc.; add 330 cc. syrup H_3PO_4 (1.7) and then 320 cc. H_2SO_4 (1.84).

Aluminium.

To the filtrate from the $Fe(OH)_3$ add strong HCl in excess and boil thoroughly 10 to 15 minutes. Add excess NH_4OH and again boil 15 minutes. For small amounts of $Al(OH)_3$ it may be necessary to prolong the boiling, and, in cases of traces of aluminium, standing over night in warm place is advisable. Filter off, wash precipitate thoroughly with hot H_2O, dry, ignite, and weigh as Al_2O_3.

Per cent. Al = wt. ppte $\times$ 53.03.

Manganese.

Weigh 1 g. borings into 300 cc. Erlenmeyer flask, add 20 cc. HNO_3, heat until dissolved and dilute to 60 cc. with hot H_2O. Add 1 g. sodium bismuthate and boil 5 minutes, or until permanganate colour which forms is changed to brown. Now add 1 g. $FeSO_4$ and boil until brown fumes are expelled and the solution resumes its green colour. Cool under tap to room temperature, add 1 g. bismuthate, agitate, and allow to stand 5 minutes. Filter by suction through asbestos and wash with 50 cc. 3 per cent. HNO_3. Dilute filtrate to 300 cc. and titrate with ferrous ammonium sulphate solution to the disappearance of the permanganate colour. A few trials will produce a satisfactory end point.

Nickel.

Weigh 0.1 g. borings into 200 cc. beaker, dissolve in 10 cc. NHO_3, dilute to 50 cc. with hot H_2O and filter into 500 cc. beaker. Wash thoroughly with hot H_2O and dilute to 300 cc. Add 10 cc. tartaric acid solution and make faintly alkaline with NH_4OH. Heat to 80 to 85 deg. C., add 50 cc. glyoxime solution, and allow to stand in warm place 15 minutes. Filter by suction through Gooch (which has been previously dried in oven at 110 deg. C. for 45 minutes, cooled and weighed) and wash thoroughly with hot H_2O. Dry at 110 deg. C. for 45 minutes, cool and weigh.

$$\text{Per cent. Ni} = \frac{\text{wt. ppte.} \times 20.31}{\text{wt. sample.}}$$

The following precautions should be observed: An excess of NH_4OH is harmful in that the red precipitate of nickel dimethyl glyoxime is slightly soluble in NH_4OH. The proper degree of alkalinity may be easily recognised by the appearance of the first permanent shade of the familiar copper ammonium blue. The solution should just barely smell of NH_4OH. The best temperature for precipitation is 85 deg. C.

In preparing the tartaric acid solution dissolve 150 g. crystalline tartaric acid in 300 cc. hot H_2O, filter and dilute to 500 cc.; in preparing the glyoxime, add to 4 g. dimethyl glyoxime in small flask 100 cc. ethyl alcohol. Connect flask to return condenser or to long piece of glass tubing, and warm on steam bath until the salt dissolves. Dilute to 500 cc. with C_2H_2OH, and filter.

Carbon.

Run direct combustion on 1.3636 g. borings by any of the common combustion methods.

PRODUCTION OF GUMS. — According to "Oil, Paint and Drug Reporter" gums, among which the most valuable are the tragacanths, are produced from small shrubs which grow all over the mountains of Mesopotamia, Southern Persia. The gums are collected by rather crude methods, and no organised trade appears to exist, due largely to the difficulties of transportation and the wild and unsettled nature of the country.

Compressed Air and Vacuum Methods of Die Casting.

A recent issue of the German "Giesserei-Zeitung" reproduces a Paper read by Herr Alfred Uhlmann, of Berlin, in which he described processes developed by himself in which the molten metal is forced into a permanent die or mould by compressed air, or sucked in by a vacuum. The process has been employed before the war for casting parts of scientific apparatus, objects used in the optical industry, motor-car fittings,

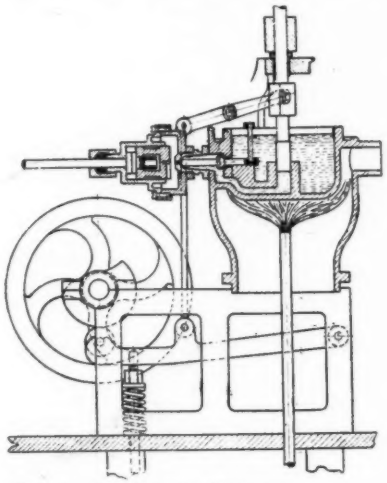


FIG. 1.—DIE-CASTING MACHINE.

parts of clocks, apparatus unsed in telephony and illuminating engineering, etc. During the war it was employed very extensively for making objects used in munition work and for military outfit in cases where a very large number of the same casting had to be produced.

The metal principally used was so-called war-metal, that is an alloy of tin and zinc, with a low melting temperature, but with certain modifications the process can be used also for casting objects in aluminium, brass, copper, bronze, etc.

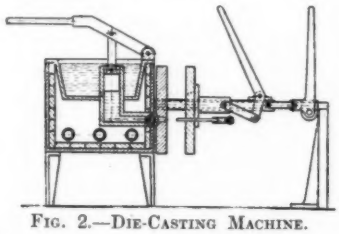


FIG. 2.—DIE-CASTING MACHINE.

Figs. 1 and 2 represent two different designs of the apparatus, but as will be seen in both forms the pump and crucible are in one in order to maintain the molten metal at an even temperature. As, in this case, the pump cylinder and piston are made of cast-iron of a special grade, the apparatus can only be used for temperatures not exceeding 500 deg. C. If, therefore, the metal to be cast has a higher melting point, like aluminium or brass, a different method has to be employed. To deal with such metals, compressed air was at first tried, which was admitted to the air-tight crucible, and spreading over the bath forced the molten metal into the permanent die, which was also made air-tight. (Fig. 3.) This method, however, did not give satisfaction. After a few trials it was found that the compressed air inflated and deformed the crucible, and thereby destroyed the air-tight joint, to maintain which was in itself a difficult problem, owing to the deformations caused by expansion and contraction under the varying degrees of temperatures.

To overcome this difficulty working with a vacuum in the die was substituted for the compressed air in the crucible, and the molten metal was sucked into the die. A variety of apparatus were developed on this principle but here again the expansion and contraction caused difficulties. The dies was deformed, and it was extremely difficult to maintain an efficient vacuum owing to leakages at the joint. At the outset the dies were almost exclusively made of tool steel, but later various other materials were tried, such as hard glass, marble, serpentine, etc.; but these materials

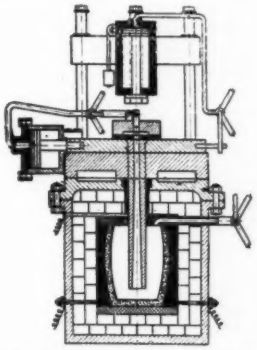
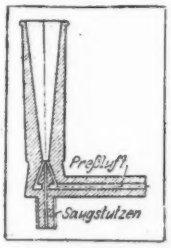


FIG. 3.—DIE-CASTING MACHINE WITH COMPRESSED AIR AND ELECTRICAL HEATING.

can only be used for casting very small objects, and without using cores or screw threads. Cast-iron, high in silicon, was, after all, found to be the most suitable material for the dies used in casting aluminium, brass, etc., because it was not attacked at all, or only slightly, by the gases given off by the molten metal.

Using a vacuum, however, did not turn out an unqualified success. At first it was impossible to keep



Presseluft = Compressed air.
Saugstutzen = Connection for suction hose.

FIG. 4.—EJECTOR.

up a constant vacuum in the mould with a suction pump, and to renew the vacuum afresh for each casting took too much time. The author then hit upon the idea of producing the vacuum by means of an ejector shown in Fig. 4, which answered very well. It created the vacuum very gently, and maintained it uniform so that the molten metal was quietly and uniformly sucked into the die. By this means sound castings were produced without airholes and free from oxides, which had given considerable trouble when the vacuum was produced by a pump.

Fig. 5 shows such a vacuum casting machine. It can be used for casting aluminium, brass, red metal, bronze, and even iron without any trouble, and thus marks a great step forward.

In order to reduce costs of labour and fuel, the author finally devised an electric furnace making use

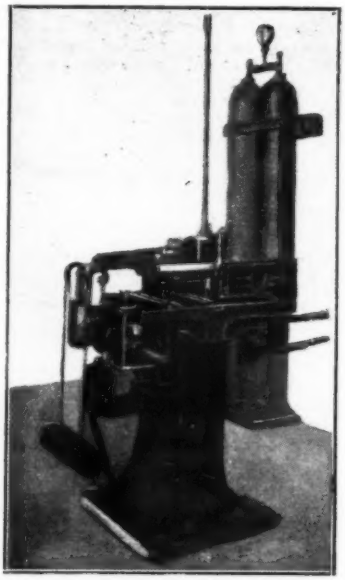


FIG. 5.—DIE-CASTING MACHINE WORKED WITH VACUUM.

of a kind of current that had hitherto not been used much in electric work. Details of this new development, however, cannot be divulged until February without endangering the patent rights for which the author has applied. As soon as these are secured, further particulars will be published.

A New Way to Heat Small Ladles.

A practical arrangement for heating a number of small ladles at a time is shown in the accompanying illustration. The device consists of a sheet-iron box reinforced with angle iron and lined with firebrick, a Hauck furnace burner and a 20-gal. steel oil tank.

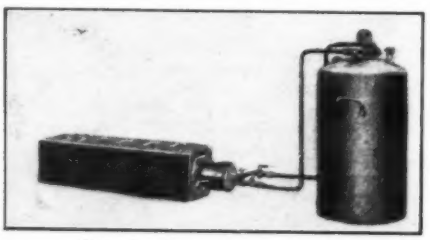


FIG. 1.—SMALL LADLE HEATER.

The ladles are placed bottom up over the opening of the box and the flame of the oil burner shoots up through the openings. The fire-box can be made any desired length to heat any number of ladles.

The burner consumes any grade of fuel, crude or kerosene oil in connection with compressed air at 20 to 100-lb. pressure. The burner is supplied with a regulating valve and is mounted on a flange which is bolted to one end of the box. The steel tank is equipped with a 150-lb. gauge, oil and air regulating valves. The connections between the burner and the tank can be made with pipe. This is a recent development of the Hauck Manufacturing Company, Brooklyn, New York.

ANTI-RUSTING PREPARATION. — Professor Zschokke, of the Swiss Government Testing Institution, has shown that chromium in the form of chromic acid and the salts of the metal has valuable anti-rusting properties when applied under proper conditions to the surfaces of iron or steel, including even the polished surfaces of machines or weapons. The most suitable strengths of the solutions would appear to be, of chromic acid 0,05 gramme per litre of water, of potassium mono-chromate 0.10 gramme, and of potassium bichromate 1.00 gramme. It is desirable to use distilled water. If to the solution of the salt sufficient soda be added to render it slightly alkaline, the preservative efficiency is increased, while complete efficiency is said to result by emulsifying the solution with certain fats.

ARC WELDING METHODS.—In a recent issue of the "Electric Railway Journal" a description is given of the function and practical operation of some types of equipment for carbon and metal electrode welding. The heat-concentration of the electric arc reduces expansion and contraction troubles, and makes possible rapid melting, and high thermal efficiency. The metal-electrode arc can be used for vertical or overhead welding. The author considers that the carbon arc is of principal value where strength and good appearance are not essential, or where the surface is to be machined-off (*e.g.*, in building up metals and plugging holes in castings). The heavy current used with carbon electrodes permits metal to be melted very rapidly. The metal deposited by either process is cast steel, and, since it is not usually subjected to any mechanical "working," it has the coarse crystal structure found in unannealed cast steel. The deposited metal should not be chilled, and the carbon arc should be long enough to prevent carbon entering the weld. With reasonable care, welds soft enough to be machined can be made by either method. Poor quality electrode or filling metal may yield hard welds. The tensile strength of the weld metal may be 55,000-60,000 lbs. per sq. in. (35,000 lbs. is a safe estimate), but the elongation and reduction in area are relatively low. Tests for the Emergency Fleet Corporation showed elongations from 4 to 13 per cent. in the weld metal. Welding equipments may be classified as constant energy, constant potential, and A.C. types. Constant energy sets use a self-excited generator driven by any convenient means. Constant energy balancer sets are suitable where 110 to 125 v., d.c., is available. A.C. welders may be used on 60-cycle, 220-550 v. supply; the welder is single-phase, but several may be distributed on the several phases of a polyphase system. Where d.c. is employed, a low voltage generator (60-75 v.) should be used, with suitable control to provide 20-50 v. at the arc. A d.c. welding set with automatic control equipment, and a typical a.c. equipment, are described. Using carbon electrodes, light work requires 150 to 250 amps.; medium work requires 250 to 350 amps.; and heavy welding 400 to 600 amps. For cutting, 300 amps. is sufficient for light work, or where speed is not important, but up to 1,000 amps. may be used for metal 2 ins. or thicker. (H. L. Unland, "Electric Railway Journal," August 16, 1919.)

Powdered Coal for the Small Foundry.

By A. J. Grindle.

In a Paper read at the recent American Foundrymen's Association, held at Philadelphia, A. J. Grindle points out that the use of powdered coal for fuel has interested foundrymen, manufacturers and engineers for over 100 years, but until the last few years its practicability has been doubted by most engineers owing to the great number of failures which have been made in its preparation and burning.

Steam boilers are being fired with powdered coal and 8½ to 11 lbs. of water per lb. of coal are being evaporated. If a foundry is equipped with a powdered coal plant it is practical to fire the core ovens with this fuel.

In addition to the fuel saving and savings effected in decreased oxidation of the metal, a saving of 25 per cent. to 75 per cent. in labour can be made. A uniform temperature can be maintained, and, therefore, a uniform product. Core ovens and steam boilers can be equipped with a thermostatic control, and the heat controlled as easily as with gas.

Heretofore the small foundry could not use powdered coal for annealing owing to the high cost of an installation compared with the possible savings, but now it is practical for even the small foundry, since it can be used in all departments where fuel is consumed.

Feeding and Burning Coal.

No matter how well coal is dried and pulverised, proper combustion cannot be secured without a uniform feed of coal, thorough carburisation with air, and means of easily and accurately controlling the coal and air supply. Equipment has been perfected which overcomes many of these difficulties.

Coals best suited for burning in a powdered form are those rich in volatile matter, such as bituminous and semi-bituminous, either slack or "run-of-mine." The slack has an advantage over the "run-of-mine" as it is not necessary to crush the former before drying.

The following analysis represents a coal which has been found to give good results on melting furnaces:—

	Per cent.
Fixed carbon...	60.12
Volatile matter	35.80
Ash	3.08
Moisture	1.00
Sulphur	.38
B.t.u....	14,650

Good results have been obtained in annealing ovens and steam boilers from coal of the following analysis:—

	Per cent.
Fixed Carbon	53.26
Volatile matter	29.00
Ash	16.34
Moisture	1.40
Sulphur	1.80
B.t.u.	12,600

Qualities of anthracite lignite and peat, as well as the inferior grades such as anthracite culm, dust and slush, and bituminous and lignite slack screenings and dust are all suitable for burning in pulverised form, for certain kinds of work, when dried and properly mixed with a higher volatile fuel. For the proper igniting and burning of powdered coal the volatile content should be 20 per cent or more, while the quality of the fuel is an important consideration, the conditions under which it is burned are more so.

The cost of preparing powdered coal for burning runs from $0.46 to $1.00 per ton depending on the amount pulverised. The cost of an installation runs from $18,000 to $150,000 according to the capacity and number of the furnaces to be fired.

Charles Longenecker in a further Paper on this same subject states:—The first installation of powdered coal burning apparatus on malleable iron annealing furnaces was at the plant of the Erie Malleable Company, Erie, Pa., where B. J. Walker adopted this method of heating in 1896. Since that time numerous other installations have been erected. The Press Steel Car Company, Pittsburgh, formerly the Pennsylvania Malleable Company, made its initial application of powdered coal to annealing furnaces in the autumn of 1917, and since then these furnaces have been in continuous operation. In this plant each air furnace is practically all below the floor level. There are 10 large and 18 small furnaces, some of which are used for annealing steel castings. The larger ones have a capacity of 50 tons, while the smaller hold 25 tons.

As is well known, the requisites in an annealing furnace from a thermal standpoint are a uniform temperature (and consequently heat) throughout the heating chamber and the maintenance of a constant degree of heat for the proper length of time. To secure these conditions, it was necessary to install four burners in each furnace and maintain a steady flow of coal to these burners. The following table shows a typical run and illustrates how well conditions have been met:—

July		
10	Noon, furnace lighted.	
11	1600° (6 a.m.)	1630° (6 p.m.)
12	1640° (6 a.m.)	1620° (6 p.m.)
13	1620° (6 a.m.)	1600° (6 p.m.)
14	1640° (6 a.m.)	1620° (6 p.m.)
15	1620° (6 a.m.)	1610° (6 p.m).
15–16	1620° (9 p.m.)	1640° (3 a.m.)
16	1620° (6 a.m.)	

From the foregoing we obtain the following summary:—

Furnace lighted, July 10, noon.

Time to bring furnace to temperature 1,600 deg., 18 hours.

Furnace held at temperature, 1,600 deg., 120 hours.

Firing discontinued, 6 a.m., July 16.

Bungs (roof) removed, 6 a.m., July 18.

The castings were then removed as soon as they were cool enough to handle.

A pyrometer is inserted in each end of each furnace. Each one is connected to a central instrument. It is the duty of the furnace attendant to read the temperature of each furnace at frequent intervals on this instrument, so that there is little chance for any wide fluctuation in temperature. One attendant supervises all the furnaces.

There is an accumulation of fine ash which must be removed from these furnaces at intervals. The length of these intervals will depend on the percentage of ash in the coal. When the coal has a low ash content the accumulation is removed once a month. In the standard type of furnace, where the heating chamber floor level is at general floor level, the disposal of ash is of small moment, due to greater accessibility of both heating chamber and flues.

As is well known, in annealing malleable castings a fluctuating temperature must be avoided and at no time is it permissible to allow the temperature to fall below the critcal range. To secure this control of the heat requires close regulation of both the fuel and the air to burn it. No trouble has been encountered in holding these conditions constant.

A comparative record of costs for three fuels is as follows:—

Natural gas, 14,000,000 cubic ft., at 35c. per 1,000 $4,900; fuel oil, 105,000 gallons at 8c., $8,400; powdered coal, 525 tons at $5 per ton, $2,625.

The figure $5 given as the cost of powdered coal includes besides the coal, all labour, power, etc. These costs are taken from actual practice and cover three separate months during each of which one of these fuels was burned.

In another malleable iron foundry where powdered coal is now burned in the annealing furnaces, a saving of 48 per cent. has been effected in the quantity of fuel consumed. In this case the amount of powdered coal burned per ton of output is 450 lbs. The time to bring the furnace to temperature has been reduced from 24 to 36 hours, required for hand firing, to 11 to 14 hours.

X-Rays Applied to Examination of Metals.

By W. E. Ruder.*

Since the announcement of their discovery in 1895, the study of Röntgen or X-rays has opened up the entire field of atomic physics and discloses much of the part that electricity plays in the structure of matter. At least two distinct phases of this study are of particular interest to the metallurgist, namely, the determination of the crystal structure, and the atomic arrangement in crystals of metals and alloys, and the examination of the physical condition of the ordinarily invisible portions of a metallurgical product. It is the purpose of the present Paper to deal only with the second of these applications, outline its technique, possibilities and limitations.

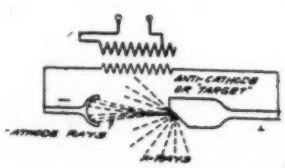


FIG. 1.—PRODUCTION OF X-RAYS.

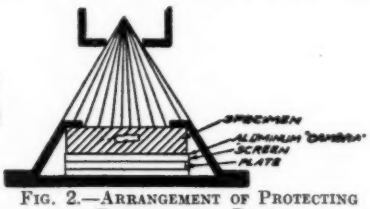


FIG. 2.—ARRANGEMENT OF PROTECTING PHOTOGRAPHIC PLATE.

X-rays are ether waves or vibrations of very short length† (.000000048 — .000000036 m.m. produced by the impact of cathode rays upon any substance (Fig. 1). Cathode rays are streams of negatively charged electrons given off by the cathode under the action of high voltage and under conditions most favourable to ionisation. These conditions may be that of a rarefied atmosphere (.006 — .001 m.m. Hg.), or of a heated cathode in a very highly evacuated tube. In either case the cathode discharge is electronic. The latter, however, represents the most advanced art in X-ray tube manufacture. Each electron in the cathode stream sets up a magnetic field perpendicular to its path, and the very rapid retardation of these electrons as they strike a substance (an X-ray target, for example) sets up electro-magnetic disturbances or ether waves of short length, and consequently great penetrating power. These are called X-rays. Rays produced in this manner have the power of producing fluorescence from certain salts of the alkali and alkali-earth metals, of ionising gases, of affecting the electric resistance of a selenium cell, of producing physiological effects in living tissue, and of affecting the photographic plate in much the same manner as visible light.

Several factors govern the effectiveness of these X-rays. First, the velocity of the impinging cathode stream which is directly dependent upon the voltage applied; second, the intensity of this stream determined as current flowing through the tube; and third, the nature of the metal in which the X-rays are produced. Waves of very short length are usually spoken of as "hard" and the longer ones as "soft." Hard rays have the greater penetration, and for this reason high voltage is required when penetration is the primary consideration. In making a radiograph, however, not only is the penetration important, but the time of exposure is directly dependent upon the amount of X-rays that reach the emulsion. The intensity of radiation diminishes as in the case of visible light rays, with the square of the distance from the point of source to the surface of the object to be radiographed.

Thickness.	Spark Gap	Expt. MA-Min.	M.A.	Distance Source to Plate.	Remarks.
.375"	10" (25.4 cm)	10	4.0	11"	No screen
.375"	10" (25.4 cm)	2^2	4.0	11"	With screen
.5 " (12.5 mm)	11" (28 cm)	7^3	..	20"	No screen
.55 " (14 mm)	10" (25.4 cm)	128	4.0	..	No screen
.55 " (14 mm)	10" (25.4 cm)	30	4.0	..	No screen
.5 " (12.5 mm)	13" (33 cm)	4	..	20"	No screen
.5 " (12.5 mm)	15" (38 cm)	1	..	20"	No screen
.56 " (14 mm)	15" (38 cm)	2.5	1.25	20"	With screen
.87 " (21.7 mm)	10" (25.4 cm)	160	4.0	15"	No screen
.87 " (21.7 mm)	10" (25.4 cm)	36	4.0	15"	With screen
.95 "	10" (25.4 cm)	60	4.0	15"	With screen
1.0 "	10" (25.4 cm)	112	4.0	12"	With screen
1.0 " (25.4 mm)	11" (28 cm)	45	4.0	20"	No screen
1.0 " (25.4 mm)	13" (33 cm)	19	..	20"	No screen
1.0 " (25.4 mm)	15" (38 cm)	10	..	20"	No screen
1.5 " (37.5 mm)	15" (38 cm)	90	..	20"	With screen
2.16 " (55 mm)	10" (25.4 cm)	650	6.0	?	
*.75 " (19 mm)	10" (25.4 cm)	5.6	2.8	22	

*Copper.

Bearing in mind the foregoing brief survey of the underlying principles governing the application of X-rays, let us now consider their application to the study of metals. Unfortunately we are at present limited

* Paper read before New York meeting of the Iron and Steel Institute, October 24th.

† Visible Light rays range from 000313 to 000330 m.m. in wave length.

in examining metals by means of a fluorescent screen such as is used by physicians, to about .01 to .02 in. thickness of metal, and obviously internal flaws in such thicknesses would be relatively unimportant. For the examination of a manufactured article, for the inspection of assembly, the screen has been successfully used. For most purposes, however, a photographic plate must be used, so that the cumulative effect of time may be utilised.

It should be borne in mind that X-rays impinging upon any substance, air, glass, wood, metal, etc., produce secondary rays which also have an effect upon the photographic plate. In metal radiograpny it becomes of primary importance to guard against this extraneous radiation by protecting the plate on all sides except in the direction in which it is desired to radiograph. This protective sheath is usually made of lead, ¼-in. thick. The aperture in the protective box surrounding the X-ray tube must be small enough to prevent the spread of the rays beyond this protective sheath. (See Fig. 2.)

Most important, however, is the protection of the operator from the action of both the direct and secondary rays. Owing to the high penetrating power of the rays used, protection is even more important in metal radiography than in radio therapeutics. Too great care cannot be taken to guard against these rays. Complete protection should always be provided for.

A suitable arrangement for the making of radiographs is illustrated. The "camera" is merely a special plate holder, light tight, of course, and carrying an intensifying screen. The object is placed on this camera directly. If the sides are not parallel, unsatisfactory results, due to unequal penetration, will result. In the case of curved surfaces, a film and flexible screen must be used.

The distance between the X-ray tube and the object is so regulated that a uniform effect may be obtained over the whole plate. For a 5 x 7-in. plate this distance should be at least 15 in.

The time of exposure is the most important consideration, and has, unfortunately, been given little attention in previous publications. It is particularly desirable in investigating a new field that all data be given. In this case, voltage, current, distance from plate to tube, time of exposure, and kind of plate should be recorded.

It is evident that, provided the voltage is high enough to cause even a small amount of radiation to pass through the metal, a radiograph can be obtained if sufficient time is allowed. The time required is also a direct function of the intensity of the rays—that is, of the current passing through the tube. The exposure may then be given in milli-ampère-minutes, at a certain spark-gap (voltage). The limit of milli-ampère-minutes a tube will stand is determined by the temperature of the target and the heating of the bulb. Most tubes, unless a special arrangement for cooling is provided, will carry only 5-6 milli-ampères continuously, at the voltage required for this work.

With the best apparatus at present on the market the metallurgist will be limited to the use of a 10-in. (100,000 volt) spark gap. This will require an exposure of about three hours at 5 milli-ampères to radiograph 2 in. of metal. This represents the present practical limits of the process. Of course, for purely research work much higher voltages are available and have been used, making the practical radiography of greater thicknesses of steel a thing to be reasonably looked forward to, but for the present this is still in the hands of the X-ray tube engineer.

The table gives results of experiments showing the time of exposure under varying conditions which gave good radiographs, and may serve as a practical guide for the determination of the time necessary. Seed X-ray plates were used:—

The Paper is illustrated by numerous radio-photographs of actual specimens.

In summarising his results the author states that from the point of view of those who are interested in the metallurgical application of X-rays, the following conclusion may be drawn:—

1. The practical application of metal radiography in the workshop, bearing in mind time of exposure and available apparatus is at present limited to about 1½ in. of steel.

2. For purely research purposes, and with special apparatus, somewhat greater thicknesses are possible of examination, but the results are increasingly harder to obtain and more difficult of interpretation as the thickness increases.

3. Only such inclusions as would, if exposed, be visible to the naked eye can be detected; hence the detection of hair-line cracks or of very small sonims is very uncertain.

Electric Wrench, Drill and Screwdriver.

A combination tool for use as a wrench, drill or screwdriver is announced by Harold Hollingshead, 55, Liberty Street, New York. A small high-speed electric motor controlled by a rheostat is encased in a metal cylinder with specially arranged steel worms and gears. All the parts are set on ball bearings, together with a specially constructed clutch having serrated teeth. The clutch has an adjustable pressure of from 10 to 60 lbs., this pressure being taken from a 10-in. leverage. This

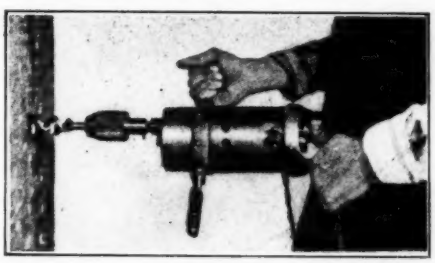


FIG. 1.—ELECTRIC WRENCH DRILL.

operates to give a predetermined torque, but automatically ceases to operate when such a limit is reached.

It is explained that a mechanical device prevents the tool from stripping the screw thread or breaking the bolts or damaging the wrench when the screw or nut is fully seated. The chuck can be placed in the clutch so that it will automatically release the screwdriver when the screw is firmly seated. When used as a wrench the power is automatically shut off after the nut has reached its intended position.

The machine shown in the illustration weighs about 14 lbs. The body is 10 in. long and 4 in. in diameter and develops from 3 to 5 h.p. in torsion. The motor operates in either direction, having three speeds forward and three speeds in reverse, on direct or alternating current at 110 to 120 volts.

ZINC-MANGANESE ALLOY. — Among the new German alloys is one of zinc with not more than 4 per cent. of manganese which is claimed to be about twice as hard as zinc itself and to have 50 per cent. greater resistance to impact, while unlike other zinc it can be forged when warm as well as stamped and rolled. The alloy can serve as a substitute for copper, bronze, and brass.

Modern Foundry Sand-Handling Equipment.

A Discussion on Mechanical Devices for Handling Sand.

Mr. H. L. M'Kinnon, writing in the "Iron Age," states the present tendency toward quantity production in the foundry has opened the way for more economical methods of handling the sand. The problem is one which rapidly increases in importance as the quantity of sand to be handled increases. This can be well illustrated by considering a foundry with a few men, making castings in a limited quantity, almost wholly by hand. In such a foundry the problem of handling the sand is simple. Enough sand may be placed on the floor in front of each moulder so that he can do his full day's work and pour off his castings, and the sand may be returned to him after the day's work is done.

When large production is in process, and many tons of sand are to be turned over daily, the cost of physical labour alone runs up into such large figures that it is essential that mechanical means be found to reduce the expense. The advent of the moulding machine into the foundry, and the consequent increase in the productive capacity of the moulder has still further added to the burden of handling sand by manual labour and has made it necessary, from an economical standpoint, to provide for mechanical sand handling. Foundries of a continuous character present additional problems which add still further to the difficulties of handling the sand manually.

Given the proper sand for any particular class of work, the first operation is the proper screening and treatment of the sand, so as to enable the moulder to use it in the production of castings. The manual processes in use for many years consist principally of the addition of water to the sand on the floor of the foundry, either before or after hand screening, and then the cutting over of the sand with a shovel or other tool, and allowing the sand to stand over night so that the water became thoroughly associated with the various particles by capillary attraction.

This method requires considerable floor space for the storage of sand, and usually makes it necessary for the sand to be worked over by a night force after the day's product has been poured. It also involves the shovelling of the sand many times before it is placed in the mould. Such methods cannot be economical in foundries of large production which handle many tons of sand every day.

Various mechanical methods are being used for handling sand in foundries. One installation is described as being used by a large foundry doing light snap flask work. In this particular installation moulding machines are operated in pairs, about 6 ft. 6 in. apart, one moulder working on a drag and the other on a cope for the same job. As rapidly as moulds are made they are laid out in the floor directly back of the moulders, where a separate pouring crew attends to the pouring of the metal and the shaking out of the moulds.

In order to facilitate the prompt return of the sand in this installation, a pan or apron type conveyor runs underneath the floor of the foundry extending the entire length of the centre of the moulding bay. Over this conveyor, at intervals, there are receiving hoppers and on top of the hopper there are gratings to prevent castings and matter other than sand from getting on to the conveyor.

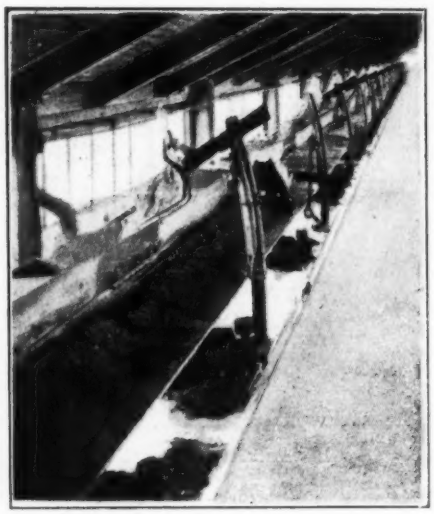


FIG. 1.—CONVEYOR FOR DISTRIBUTING TEMPERED SAND.

FIG. 2.—TEMPERED SAND STORAGE, SHOWING PROVISION FOR FEEDING BELT CONVEYOR BELOW.

The conveyor delivers the sand to what is called the scalping or roughing screen which removes pieces of coke and such small foreign substances which get into the sand. The screened sand then drops into an elevator and is carried to the top of the treating building where it is again screened. After screening, water is added and the water and sand are thoroughly milled in a centrifugal machine which produces a uniform product.

The control of the water supply is in the charge of an operator who is held responsible for adding the proper amount to put the sand in ideal condition. From the milling process the sand drops into a storage bin where it is allowed to rest for a definite period in order that capillary action may take place and the moisture become thoroughly distributed through the particles of sand. From this point the sand is fed upon belt conveyors and distributed to the moulders, the hopper for each moulder being placed above his machine, so that he can drop the sand directly on the mould if he desires.

In the handling of moulding sand, a few important general principles should be kept in mind. It is never desirable to handle tempered sand in a bucket elevator if other means can be used. The reason for keeping away from the bucket elevator for this service is that the tempered sand has a tendency to fill up the buckets and requires frequent cleaning in order to maintain the operating capacity. If the sand is handled as it comes from the moulds it is generally dry enough so as not to involve this difficulty.

For the distribution of the tempered sand, in the author's judgment, there is nothing so satisfactory as the flat rubber conveyor belt, even though reciprocating flight conveyors have been used with more or less success. One of the main objections to the reciprocating conveyor is the amount of power required to operate it as compared with the belt conveyor. A further objection is that there is a marked tendency to produce small balls of sand about the size of peas or beans which are detrimental to the obtaining of smooth castings.

The use of the rubber conveyor belt is recommended because it possesses a smooth operating surface which cannot become impregnated with the sand and which

FIG. 3.—INDIVIDUAL OVERHEAD SAND HOPPERS.

resists wear for a long period. The writer recently viewed a belt of this character which had operated through the equivalent of nine years' continuous daily service. The belt is 240 ft., centre to centre, and handles approximately 250 tons of sand daily. It has been operating for seven years, but during the years 1917 and 1918 worked double shift. At the time it was viewed by the writer it was still in good working condition.

The device for removing the tempered sand from the belt conveyors is simple, and consists of nothing more than a curved plate placed so as to act like a plough and turn the sand over at the desired point. These plough plates are hinged at one end so that they may be lifted out of the way, allowing the sand to pass to any other desired point. (See illustration, Fig. 1.)

One of the principal difficulties which has been met in foundry sand handling has been the problem of properly withdrawing the tempered sand from the storage bin after it has been placed there. The type of feeder shown in Fig 2 meets the condition more satisfactorily than any other. It is easily adjusted, and seems to have the peculiar motions which are best adapted for cutting the sand and removing it from the bin in a regular manner.

A magnetic separator is required in the cleaning room of large gray-iron foundries for the purpose of separating core rods, nails and other magnetic materials from the core sand itself. The individual overhead sand hoppers are illustrated in Fig. 3.

Mechanical sand handling is entirely practical where the quantity of sand is great enough so that the cost of conveyor equipment, as an overhead expense is not too great. In general it seems to be possible to put in a sand handling equipment on duplicate work where there is a minimum of 150 to 200 tons of sand to be handled daily. In some instances where the work is highly concentrated a much smaller amount of sand than this can be handled economically.

The frequency with which moulding sand may be re-used depends primarily upon the dryness of the sand before tempering, that is, if very light castings are being made and the temperature of the sand is not greatly increased, such sand can be used more frequently than that which becomes highly heated.

The problem of sand handling is simple. The less apparatus that can be used to accomplish a given result is in most cases the most satisfactory. This is due partly to the difficulty of obtaining proper mechanical attention to equipment in most foundries; but without proper mechanical attention there is no equipment that will prove satisfactory and give continuous service. In considering mechanical equipment it is extremely desirable that the question of mechanical attention be fully considered.

There is no reason why mechanical sand handling equipment cannot be produced to meet any set of conditions, providing there is sufficient sand to handle to justify the initial expense. If properly arranged, mechanical sand handling equipment should result in increased production per square foot per man on any given floor space. This has been demonstrated repeatedly. Ample proof in the form of many successful installations is available for anyone who cares to investigate.

NEW PROCESS OF RUBBER MANUFACTURE.—The "Scientific American" reports that an English chemist has demonstrated on a laboratory scale a process which may revolutionise the methods of rubber manufacture, if it proves as successful on a commercial scale. At present the latex must be converted into rubber within 24 hours from the time it is extracted from the tree, to prevent putrefaction, but when treated by the new process it is said that it can be kept for any time. It now takes at least a fortnight to bring raw rubber into condition for transmission to the market, but the new process reduces this time to 30 minutes.

WEATHERING OF TIMBER. — The Fairbanks, Alaska, Station of the Bureau of Mines has recently completed two series of tests to determine the comparative steaming value of Alaska lignite and spruce wood, and the resistance of lignite to weathering when stored in piles in the open. The results showed that pound for pound, the value of spruce wood lay between two samples of lignite used, but that a cord of wood is equivalent to more than a ton of lignite. The weathering tests showed that the average loss in weight through weathering was about 6 per cent., and that the weathering after 14 months was only slightly more than after one month. In large piles, only the surface to a depth of about 5 in. would be affected.

THE DETERMINATION OF OXYGEN IN GASES —The use of the copper-ammonia-ammonium chloride reagent for the determination of oxygen in gases is described by W. L. Badger in a recent issue of the "Journal of Industrial and Engineering Chemistry." As a result of his investigations, the author concludes that the solution of ammonia and ammonium-carbonate as recommended by Hempel is not satisfactory. The most convenient solution is made by saturating with ammonium chloride, a mixture of one part concentrated ammonia and one part water. This solution will absorb 50 to 60 times its volume of oxygen. The advantages claimed are that it is cleaner to use and has a longer life than an alkaline pyrogallic acid solution, and that it is active at almost any temperature. It cannot be used with gases containing carbon monoxide and acetylene.

An Improved Moulding Machine.

A patent has recently been granted to Messrs. J. Shepherd and W. H. Hickling, of Messrs. J. Shepherd & Company, Leicester, for an improved type of machine for making moulds and cores, particularly for use in the casting of pipes.

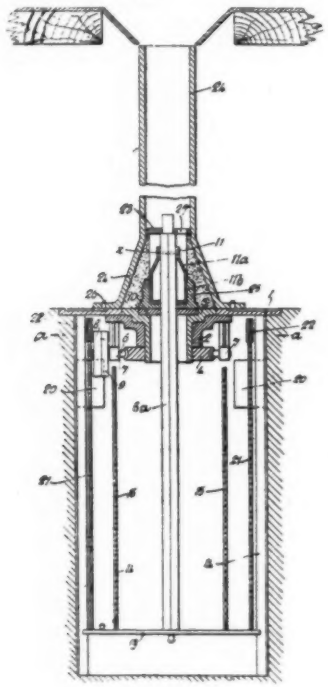
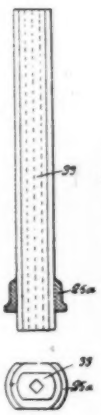


FIG. 1.



FIGS. 4-5.

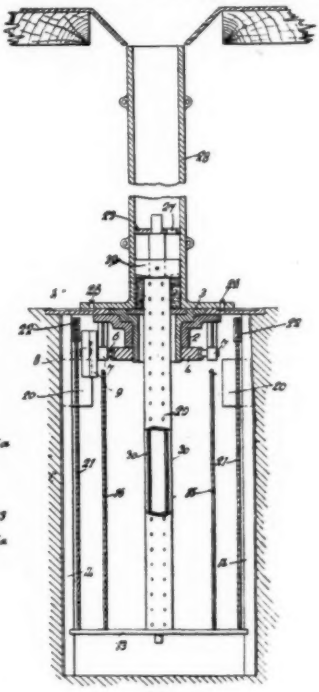


FIG. 2.

The invention consists of a moulding machine characterised by the arrangement that the longitudinal member carrying the rammer or moulding instrument passes through and is rotated by a revolving table combined with the fixed base plate which supports the mould box, said member being moved endwise through the table to advance the rotating rammer through the material in the mould box by mechanical elevating means situated below the base plate.

By actuating the rammer or moulding tool entirely from below, an economy in head-room is effected this being particularly the case when making a long mould or core.

The machine is diagramatically illustrated in the following figures. Fig. 1 shows the machine as adapted for making pipe moulds. Fig. 2 shows the machine adapted for making cores. A cross-section of the machine along *a a* in Fig. 1 is illustrated in Fig. 3 and the pipe pattern for a spigot pipe in Figs. 4 and 5. The small figures refer to a complete description of the mechanism which can be obtained by reference to the original specification, No. 136,925, 1919.

The broad principles involved in the use of the machine will be readily apparent from the illustrations.

Upon the machine being started, as the pattern 25 and rammer 11 rotate, the wedging action caused by the oval shape of these rotating members and the conical part 11a of the rammer, packs and binds the sand on the inside of the mould box 24. As the rammer rotates and rises, the action of its conical or spiral upper part 11a and its lower parallel part 11b rams and binds the sand into a hollow cylindrical form inside the box, the parallel part 11b leaving a cylindrical hole in the mould equal in diameter to the greatest diameter of the said part, it being understood that the guide 23 is raised by the shaft 6a as the latter rises and constanly keeps the rammer and shaft central. The guide has suitable openings 27 formed in it to allow the sand to pass there through to the underside to be acted upon by the rammer. When the rammer rises, it passes out of the pattern 25 leaving the latter behind on the revolving table. The pattern continues to be rotated by the shaft 6a which

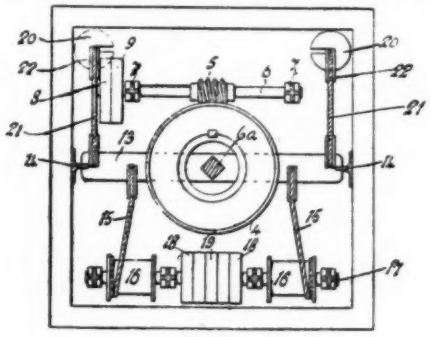


FIG. 3.

passes upwards through the hole in the base of the pattern.

When the shaft 6a has risen high enough to lift the rammer out of the upper end of the mould box, the guide and rammer are removed from the shaft which is then lowered and the mould box with its moulded sand is lifted off the base plate, such as by a

crane, the pattern 25 is removed and the operation of moulding may be repeated with another box.

In using the machine or apparatus to make a core, a mould box 28 (Fig. 2) of the size and shape of the core is used, and the vertical shaft is replaced by a core bar or barrel 29. The barrel is employed in a similar manner to the shaft 6a aforesaid and carries at its upper end a rammer 32 and a guide 23. When the core barrel and rammer are in the low position, the box 28 is filled with sand after which the machine is started. As the core barrel and rammer rotate and move upwards, the rammer, which has bevelled or inclined underfaces, packs and binds the sand in the box 28 and produces a hole corresponding in size to that of the core barrel 29 so that the latter as it follows the rammer upwards fills the hole and is left in the sand after it has been moved upwards therein to the desired extent.

In the formation of a pipe mould, instead of simply employing the rammer 11 on the upper end of the shaft 6a, the rammer may be followed by a pattern 33 such as shown in Figures 4 and 5 which is made parallel and of a length equal to that of the mould and in diameter is equal to that of the hole formed by the rammer. This pattern, which is flattened on opposite sides, fits concentrically upon the shaft 6a and travels with the latter as it rotates and moves upwards. In this case the socket pattern 25a is provided with a through hole of the same shape as the cross section of the pattern 33 so that the latter may pass up through the socket and also rotate same.

By using the pattern shown in Fig. 4 it is possible to make the full length of the casting as follows : The moulding box 24 is placed upon the base plate I. ; then the pattern, which rests upon guide bar 13, is raised through the base plate to the top of moulding box. After filling up with sand, the pattern is lowered into the pit. The mould and box are then lifted and taken to a place preparatory for drying, previous to casting.

Endurance Tests on Cast Steel.*

Dr. Erdman Kothny, of Traisen, in Germany, recently induced the works manager and the head of the testing laboratory of a local steel foundry to carry out a series of endurance bending tests on soft cast-steel bars according to his directions with a view of ascertaining how far heat-treatment affected the results.

The tests were carried out on an Amsler bending machine on round bars. It should be explained, however, that the machine was used for carrying out tests on bars with two projecting ends, while Dr. Kothny's tests were carried out with bars with one projecting end only.

The subjoined table shows the results of the tests. Nine pairs of bars were tested, each pair of which was treated differently, as under :—

Bars 1 and 2 underwent no heat treatment at all, while all the others were heated to 950 deg. C.

Bars 3 and 4 were heated to 950 deg. C. and quenched in water.

Bars 5 and 6 were treated in the same way as 3 and 4, but after quenching were re-heated to and kept at a temperature of 400 deg. for 15 minutes.

Bars 7 and 8 were treated in the same way again, except that they were re-heated after quenching to and kept at 600 deg. for 15 minutes.

Bars 9 and 10 were also treated in exactly the same way, but the temperature to which they were re-heated and kept at for 15 minutes was 900 deg.

The next pair of bars, 11 and 12, were heated to and kept at 950 deg. for 5 minutes and then allowed to cool in the air.

* Giesserei Zeitung, December 1919.

Bars 13 and 14 were heated in the same way as 11 and 12, but were allowed to cool in the furnace.

Bars 15 and 16 were again treated the same way, but they were only allowed to cool down to 600 deg. in the air and then to cool in the furnace.

Finally bars 17 and 18 were also heated to 950 deg., but kept at that temperature for 4 hours and then allowed to cool in the air.

The heat treatment of bars 8 and 12 not having been quite correct to plan, the results of these tests were disregarded in computing the averages.

The Brinell numbers are not given by our author, but have been computed from the tenacity in kgs. per sq. mm. by the use of the following formula :—

$2.762 \times$ pressure in kgs. per sq. mm. = Brinell number.

The bars were held at one end and loaded at the free end and were then rotated and bent in the machine beyond the elastic limit by an electric motor at the rate of 1,000 revs. per min. The number of revolutions was automatically recorded on a dial, the hand of the counting apparatus stopping automatically when the bar broke through fatigue. The weight of the load was 50 kgr. (110 lbs.), of which the bottom disk and the suspension gear represented two-fifths.

The author does not seem to be wholly satisfied with the results obtained, as they lead to no definite conclusion. Another series of similar tests will therefore be made.

Number of test bar.	Brinell number.	Number of revs. before failure.	
		Individual.	Average.
1	112	18,179	41,289
2	110	64,400	
3	163	558,581	529,700
4	173	500,820	
5	156	146,260	161,740
6	159	177,220	
7	149	135,520	135,520
8	114	92,650	
9	126	209,320	181,519
10	128	153,700	
11	116	140,940	140,940
12	118	72,146	
13	107	123,910	271,050
14	116	418,200	
15	112	188,820	160,035
16	112	131,250	
17	124	351,250	298,742
18	121	246,234	

He repeatedly reminds us that the tests were carried out on soft cast steel. He publishes in another part of his Paper the results of the tensile tests which, according to the heat treatment of he bars, varied from 24.765 tons per sq. in. (elastic limit 17.145 tons) to 29.845 tons per sq. in. (elastic limit 20.955 tons), the corresponding elongations being 18.7 and 15.9 per cent. respectively, and the contractions 25.6 and 24.5 per cent. The distance apart of the pop marks was fixed by the formula :

$$\text{Distance} = 11.3 \sqrt{\text{area}}.$$

both in millimetres.

The chemical analysis of the metal gave the following results : Carbon, 0.10; manganese, 0.52; silicon, 0.15; phosphorus, 0.03; sulphur, 0.05 per cent. The quenching temperature (950 deg.) was fixed by preliminary trials.

Electrically-Heated Metal Pattern Plates.

In the December issue of the "Canadian Foundryman," a new form of electrical heating device for plate moulding machines is described. The usual method of heating is by means of a gas flame left burning in the space underneath the pattern within the frame-work of the moulding machine. It is difficult to keep the flame low enough so that it will not heat the pattern too much. A larger flame than necessary is, therefore, employed at some distance from the surface of application. This makes an inefficient arrangement, as most of the heat is dissipated into the surrounding space. The surrounding air becomes contaminated by the gas fumes, and in summer there is the further discomfort due to the heating of the surrounding air.

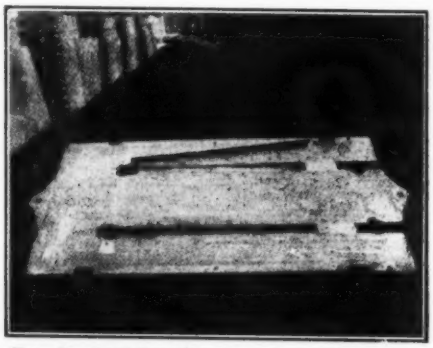


FIG. 1.—SHOWING ARRANGEMENT OF ELECTRIC HEATER.

Difficulty is experienced due to variation of gas pressure, so that at one time the pattern is too hot and at another too cold. When the pattern gets too hot, it is necessary to cut off the gas, and when it has cooled down, re-light and readjust the gas. In some sections there is a scarcity of gas.

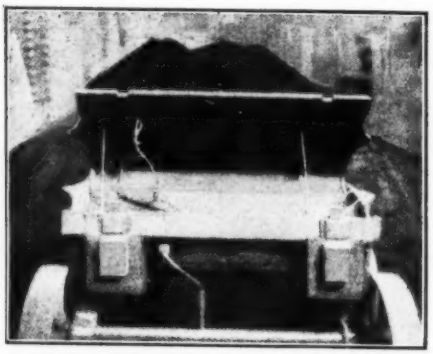


FIG. 2.—SHOWING BOTTOM FACE OF TABLE WITH ELECTRIC LEADS.

A much more convenient method of heating is by the use of electric heaters, as shown in the photographs. Two steel-clad heaters are shown in Fig. 1 mounted in the space immediately below the metal pattern plate, within the frame-work of the moulding machine. In order to use as little heat as possible, they are located just below the thickest pattern used. They are attached to simply supporting angles attached to the frame of the machine. It is obvious, then, that any pattern of any thickness and of any size within the capacity of the machine may be attached to or removed from the moulding machine without being interfered with by the heaters, and without disturbing the heaters whatever. To conserve heat, an asbestos insulating plate is placed just below the heaters, to prevent loss of heat due to radiation downward from the heaters. The entire installation is made in such a way as not to interfere in any way with the usual operation of the machine, including the mechanical vibrator, and without any modification of the machine other than to drill and tap small holes for attaching the mounting angles.

As stated above, the heaters are of the steel-clad type. For the moulding machine shown in Fig. 2, taking a pattern plate 16 in. by 11 in. by 2 in., there are two heaters, each 13 in. long by 2¼ in. wide by ¼ in. thick overall. They consist of slotted ribbon resistors of high resistance, temperature resisting alloy insulated in mica troughs, the whole being encased in a heavy sheet steel casing. There is a mounting lug on each end with holes punched in for mounting the heaters. The heater terminals are mounted on one end of the heater casing and are protected by a substantial terminal cover. The two heaters used on each machine have a total rating of only 300 watts, and operate on 110 volts. The heaters are permanently connected together electrically, and connection is made to a wall receptacle convenient to the machine by means of a flexible heater cord, having a separable attachment plug on the end.

The advantages of this heater over gas are obvious. Instead, it is only necessary to plug into a wall receptacle and give no further thought to the matter, since but one degree of heat, and that the correct one, can be obtained.

FATIGUE OF METALS.—It has been generally assumed that if one keeps within the "elastic limit" of a metal—that is to say, broadly, if the metal is not stretched beyond the point whence it can instantly recover itself—it is possible to go on stressing it an infinite number of times without risk of failure. Whether this assumption is correct has not really been determined, but the tendency at the moment is to conclude that if an "endurance limit" exists it must be not only within the elastic limit of the metal, but well within it as determined by the usual static tests. The question is obviously of vital importance in engineering construction, and is one of those which must form a subject of lengthy research in the immediate future. In the life of a turbine steam engine the shaft may be stressed some 15,000,000,000 times.

THE NATIONAL ASSOCIATION OF INDUSTRIAL CHEMISTS.—This association, which claims to be the only one which watches the interests of all analytical chemists, is progressing favourably. At the recent meeting of the executive Council a further increase in membership was reported, and the Association has now appointed a full-time assistant secretary. It has also been registered under the Trade Union Act, and is the only body representing analytical chemists in the United Kingdom which is so registered. With the newer powers thus granted to it, the Association expects considerably to increase in its influence and its ability to assist the economic condition and professional status of its members. Special arrangements are being made to give isolated members an equal share in the management of the Association with those belonging to a local section. After considerable discussion, it has been decided to continue the subscription at one guinea for full members and half-a-guinea for associates. Further particulars can be obtained from the Secretary, The White Building, Sheffield.

Trade Talk.

DURING a gale on May 13 a new foundry in the course of construction at Muirhall, Larbert, was blown down and completely demolished.

CAMMELL, LAIRD & COMPANY, LIMITED, Birkenhead, have received an order for the construction and equipment of a refrigerator steamer for the Union Cold Storage Company.

SIR GEORGE PERLEY, High Commissioner for Canada will open the Exhibition of Canadian Products at the Royal Agricultural Hall, Islington, on Thursday, June 3.

THE North-Eastern Railway Company have just placed a repeat order for twenty-five 6-coupled side tank locomotives, with Sir W. G. Armstrong, Whitworth & Company, Limited.

THE AUSTIN MOTOR COMPANY, LIMITED, propose capitalising £200,000 of the undivided profits, and issuing an equivalent number of fully-paid shares to the ordinary shareholders.

WE learn from the "Foundry World," the mouthpiece of the H.M. Lane Company, that they have secured the services of Mr. John Rathbone. Mr. Rathbone is an expert not only in moulding machine-work, but also in the centrifugal casting of metals.

IN connection with the purchase of the National Shipyard at Chepstow, the interested parties have asked the Government for a rescission of the contract, on the ground that the contract had been entered into on the strength of the statement that the Excess Profits Duty would be taken off altogether.

A SERIOUS fire causing heavy damages recently broke out at the premises of Messrs. Barclay, Ross & Hutchison, agricultural implement makers, Aberdeen. One building, a timber store and paint shop, was completely gutted; and the millwrights' shop was seriously damaged.

THE DRUM ENGINEERING COMPANY, LIMITED, 28, Humboldt Street, Bradford, have taken over the business carried on by the Drum Engineering Company and that of Saville & Duncan, Limited. The combined businesses will be carried on under the personal supervision of Mr. C. E. Johnson and Mr. H. E. Duncan.

AT a recent meeting of the London and Southern District Junior Gas Association, Mr. L. F. Tooth, M.B.E., of the Commercial Gas Company, lectured on "Gas Apparatus Used During the Late War in Connection with the Manufacture of Fuses." The lecture dealt primarily with the use of "G" brass, for fuses, primers, nose-bushes, and other component parts of shells.

A DISASTROUS fire which raged at the central shipyard of William Gray & Company, Limited, West Hartlepool, did heavy damage. The fire broke out among the timber stocks, and the timber drying shed, covering a large area, was soon burning. A high wind caused the flames to spread to the joiners' shop, the platers' shop, the general stores, and the fitting shop, all of which were destroyed.

SIR W. G. ARMSTRONG, WHITWORTH & COMPANY, LIMITED, have now made arrangements to undertake the manufacture of water turbines, and have formed a hydro-electric section as a part of their civil engineering and contracting department, which is under the control of Mr. Mackenzie. The designs to which they will work are those of a Norwegian firm who have been making water turbines since 1849.

THE BARROW HEMATITE STEEL COMPANY, LIMITED, and the Millom and Askam Hematite Iron Company, Limited, have recently concluded negotiations for the purchase of all the shares in the Wyndham Mining Company, Limited. The Wyndham Mines are well known in Cumberland, are close to the town of Egremont, and are not far distant from the Florence Mines of the Millom Company and the Ullcoats Mines owned chiefly by the Barrow and Millom Companies.

MESSRS. BUCKLEY, SAUNDERS & COMPANY, LIMITED (E. A. CHANTLER), have secured the agencies for South America for the Wild-Barfield Electric Furnaces, and also for the Argentine for the A.I. Manufacturing Company's electric welding machines. Demonstration plants are already erected and working at the works in Buenos Aires and can be inspected by applying at the offices, 314, Bme Mitre. A demonstration Wild-Barfield electric furnace will also be in operation shortly in Rio de Janeiro.

THE Ding Dong tin mine, near Penzance, Cornwall, which was closed down early in the war, has changed hands, and has been reopened. This mine is reputed to be the world's most ancient tin mine, and is stated to have been intermittently worked since the time of the Phœnicians, over 2,000 years ago. Some authorities claim that the tin used as an alloy in the casting of the enormous brass castings used in Solomon's Temple was taken from this mine.

THE ASTER ENGINEERING COMPANY (1913), LIMITED, was formed for the purpose of acquiring an engineering business founded some 14 years earlier. The capital is £180,000 divided into 100,000 8 per cent. cumulative participating preference shares of £1 each, and 80,000 ordinary shares of £1 each. To enable the company to cope with its increasing business and to extend its operations additions are being made to the works. With the object of providing the necessary funds, an issue has been made recently at par of 100,000 preference shares.

THE directors of Beyer, Peacock & Company, Limited, have under consideration a scheme for the extension of the works buildings, and a new boiler shop is at the present time in course of erection. Additional expenditure will thus be required for new machinery, and further working capital will be needed. The directors, therefore, in order to provide for these and possible future requirements, have decided to recommend that the authorised capital be increased by £800,000. It is also proposed to alter the articles of association so as to permit of the capitalisation of undivided profits.

A NEW publication of the Bureau of Standards, Scientific Paper No. 361, "Magnetic Testing of Straight Rods in Intense Fields," discusses previous experiments on high inductions and describes a method which is suitable for measuring the magnetic properties of fairly long rods of ferromagnetic materials, when magnetised in intense fields. Normal induction data are compared with those obtained by the Burrows method and found to agree satisfactorily within the range of the latter. From the normal induction data, the intensity of magnetisation and reluctivity are calculated and discussed.

THE engineering business of Thornewill & Warham, established in 1732, after being in the hands of a receiver for practically five years, was reconstructed last year under the title of Thornewill & Warham (1919), Limited, with Mr. F. C. Pulsford as managing director, Mr. J. E. Schofield as manager, and Mr. G. J. F. Black as technical representative. The latter was one of the directors of the old company and has joined the board of the new organisation. A dividend of 12½ per cent. has been declared after making satisfactory provision for depreciation and carrying £1,000 to the general reserve account.

AN important communication, says the "Chemical News," on the spectra of isotopic lead and thallium was brought before the Royal Society, London, by T. R. Merton. Interferometer measurements of the principal line in the spectra of ordinary lead and in lead from pitchblende showed that, in the latter case, the line was less refrangible by 0.0050A., whereas the lead from Ceylon thorite was more refrangible by 0.0022A. Thallium, which occurs in pitchblende in very small proportion, was examined by alloying it with pure cadmium and was found to give a line more refrangible than that of ordinary thallium by 0.0055A.

THE MINISTRY OF AGRICULTURE AND FISHERIES and the Board of Agriculture for Scotland have come to

an agreement with the makers of ground basic slag with regard to the maximum prices to be charged for this fertiliser in the season 1920-21. These prices are the maximum net cash prices for ground basic slag in maker's 2 cwt. bags, delivered in railway truck or free ex barge or ship at purchaser's or consumer's railway station or wharf in Great Britain or, in the case of shipments to Ireland, the Channel Islands, or the Isle of Man, carriage paid to station at port of shipment in Great Britain. The prices range from 82s. to 147s. per ton for 12 per cent. to 44 per cent. phosphates respectively.

THE COUNCIL OF THE INSTITUTION OF CIVIL ENGINEERS have made the following awards for papers read and discussed during the session 1919-1920 :—Telford gold medals and Telford premiums to Mr. D. Lyell (London), Mr. J. K. Robertson (London), and Major-General Sir Gerard M. Heath (London); a George Stephenson gold medal and a Telford premium to Mr. M. F. Wilson (London); a Watt gold medal and a Telford premium to Mr. P. M. Crosthwaite (London); Telford premiums to Major E. O. Henrici (London), Sir Francis J. E. Spring (London), Mr. F. O. Stanford (London), Mr. J. Mitchell (Hursley), Mr. J. W. Sandeman (Newcastle-on-Tyne), and Mr. A. R. Fulton (Dundee).

RECENT contracts for the installation of the Greaves-Etchells type of electric furnaces includes the following :—W. Weddell Engineering Company, Birmingham, ½-ton; Reliance Steel Company, Limited, Wolverhampton, ½-ton; G. C. Carlisle, Sheffield, ½-ton; Sheffield University, ½-ton; S. Marley, Newcastle, 1 ton; A. Hamilton, Cardiff, ½-ton; Stora Kopparbergs Bergslags, Sweden, 20 tons; Imperial Japanese Mint, ½-ton; Hongkong Steel Foundries, 1½ tons; Brazil Military Commission, 1 ton; Chilian Naval Commission, 1 ton; Metallurgique de la Noire, St. Etienne, two 7½ tons each; Bird, Archer & Company, Cohoes, New York, ½-ton; J. & S. Wayne & Company, Croghan, U.S.A., 3 tons; Hoskins, Limited, Detroit, U.S.A., ½-ton; Dodge Steel Castings Company, Philadelphia, U.S.A., 3 tons.

H. J. SKELTON & COMPANY, LIMITED, of Royal London House, London, E.C., have been appointed sole purchasing agents in the United Kingdom, for the Compagnie De Fives-Lille. This company are purchasing in the United Kingdom plant and materials amounting to upwards of £2,000,000 sterling in value, and consisting of iron and steel material for building bridges, locomotives, boilers, electrical plant, machinery, etc., required in connection with the reconstruction and operation of their works in Northern and Eastern France. When completed, the locomotive works of the Fives-Lille Company will have a monthly capacity of 40 locomotives. The additions to their plant include bridge works, boiler shops, steel and iron foundries, forge, electrical engineering shops, etc. Messrs. Skelton have also been appointed purchasing agents for a consortium of Italian shipbuilders and likewise for one of the largest Japanese shipping and metal houses.

CONDITIONS of sale relative to structural steel work for export for bridges or buildings have been standardised by the Steel Structural Section of the British Engineering Association. They are :—(1) Prices quoted to be "nett cash" unless otherwise stated; (2) If price is required for steel work only delivered f.o.b. British port, payment should be made "Cash against Shipping Documents in London"; (3) If price required for structures delivered and erected, payment should be made as follows :—80 per cent. against shipping documents, 15 per cent. monthly on the value of erected work, and balance of 5 per cent. in one month after completion of contract. Considerable time will be saved if bankers' or other suitable references are forwarded with preliminary inquiry, while all work is to be inspected and accepted at the makers' works. A specification covering materials to be used and the general construction of the work is to be submitted with the tender.

WILLIAM BEARDMORE & COMPANY, LIMITED, have now completed their arrangements for the construction and repair of railway locomotives on an extensive scale at both their West of Scotland establishments. The department at Dalmuir which was used during the war for the manufacture of mountings for all classes of guns has been changed over completely, and is now devoted wholly to the construction of locomotives. The machinery in the shops was rearranged and new plant was installed whenever necessary. This involved structural alterations and the strengthening of the original buildings; while, in addition, new railway lines were laid connecting every shop in the department with the lines inside the shipyard, and thus with the main line system of the Caledonian Railway Company. Although the change over from war work to locomotive construction has been completed at Dalmuir, the firm's largest locomotive department will ultimately be at Parkhead, where the armour and ordnance shops are being converted for the same purpose.

UPWARDS of 150 members of the Manchester Association of Engineers recently inspected the Knott Mill Works of Galloways, Limited, Manchester. Apart from viewing generally the various departments of the works, the visitors' attention was directed to the following engines which were being completed :—Large Uniflow engine with 60-in. cylinder, 6 ft. stroke—the engine was not in motion, but the valve gear and the governing arrangements were specially driven by electric motor; horizontal gas engine of 1,850 b.h.p., for the Barrow Hematite Steel Company, Limited—cylinders 1,150 mm. diameter, stroke 1,300 mm.; three-crank reversing rolling mill engine, with three 40-in. cylinders, 4 ft. 6 in. stroke, approximate h.p. 8,000. The Uniflow steam engine is believed to be the largest of its type in the world and is being made for John Lysaght, Limited. It is intended for driving a mill rolling steel sheets, and will run at 28 r.p.m., at which speed the normal power will be about 1,500 h.p. The engine is capable of developing double this normal power when running at greater speed.

THE report of the Wolfram Mining & Smelting Company, Limited, for the year to September 30 last states that the period under review has been a difficult one. Immediately following the armistice the price of wolfram was dropped from approximately 55s. per unit to 30s. per unit, which made it impossible for any wolfram property to continue working at a profit. Moreover, in view of the big stocks held by the Ministry of Munitions, which would have to be absorbed over a long period, the outlook for producers was not a bright one. Owing to the high pressure at which the mill was kept running during the war a complete reorganisation and reconstruction of the plant has become absolutely necessary. With the exception of power plant, most of the machinery was in a very bad state, and, considering both mine and mill had been worked day and night, it was found essential to close down the mill. Consequently milling was suspended in June. Development of the mine has continued, and it is intended to continue opening up the mine until the new mill is completed. Mine development has yielded satisfactory results, and a good supply of ore should be available for treatment when the mill is ready.

THE HENDY HEMATITE IRON ORE COMPANY, LIMITED, was formed in August last year for the purpose of developing the hematite ores in the Glamorgan field, the company having acquired a mile of ground between the Cardiff Road and the railway at Pontyclun, where they are driving a level. The site is on the west extension of the old Bute Mine, which was worked from about 1854 to 1880, and in close proximity to the Mwyndy Mine, which was abandoned in 1854 after being worked for some 30 years. The present level, 6 ft. x 7 ft., has been driven for a distance of 100 yards, and it is anticipated that the main ore deposits will be cut at about 300 yards from the surface. The level will cut practically through the centre of the ore

bed, and the first objective of the company will be to win the top ores, for which the inclination of the level will afford natural drainage. When these have been opened up, it is proposed to sink a staple pit, to put down pumps and work the lower measures. The Pontyclun level may well be regarded as the initial step in operations which appear likely to assume considerable magnitude, as the company have acquired very extensive options in what may be termed the Taffs Well-Llanharry ore field Mr. J. H. Bennetts, the general manager, is also a director of the company.

ACCORDING to the Comptroller and Auditor-General's report on the accounts of the Ministry of Shipping for 1918-19, the total expenditure on national shipyards brought to account to March 31, 1919, amounts to £4,794,498. This sum includes £2,350,327 paid to the War Office who through the Inland Waterways and Docks Department, constructed the shipyards for the Admiralty under agreement whereby the amount charged to the Admiralty for military labour and supervision should be the "cost account total." The claim by the War Office included £1,158,844 for labour and supervision, a sum which the Shipping Controller considered to be unreasonable as the cost accounts showed that the cost of the military officers and men engaged on the work was £523,657 only, but in the end the Shipping Controller paid the claim in full. The shares in the Standard Shipbuilding and Engineering Company were purchased by the Admiralty at a total cost of £656,250, being 35s. for each fully paid £1 share, and 8s. 9d. for each 5s. paid share. The Controller-General of Merchant Shipbuilding expressed the opinion that the acceptance of the offer of the company to sell at the above figure would be a good bargain for the Admiralty, notwithstanding that no expert valuation of the plant had been made on the part of the Government. The Treasury in sanctioning the proposal to purchase in this form stated that they would have felt considerable difficulty in doing so had it not been for the very definite opinion of such an experienced shipbuilder as the Controller-General. The liabilities, states the report, were £129,767, which with a payment of £3,283 for stamp duty on the transfer of the shares and the deduction of £34,094 for cash received from various debtors, makes the net cost of purchase £755,206. The greater part of the property purchased from the Standard Shipbuilding Company, together with certain machinery and stores, has since been sold for £600,000, and a deposit of 10 per cent. of the purchase money was brought to account on March 4, 1920.

A MEETING of those financially interested in the scheme for the consolidation of the iron and steel interests and resources of Canada and the United Kingdom was held at the office of Lieut.-Colonel W. Grant Morden, M.P., 8, Waterloo Place, London, S.W.1, on April 21, to receive the report of the Hon. Sir Newton Moore, K.C.M.G., M.P., and Mr Benjamin Talbot, with reference to the interests secured in the Dominion Steel Corporation and the progress made towards amalgamating with the Nova Scotia Company. The Hon. Sir Newton Moore, who recently visited Canada on behalf of the Syndicate, with Col. Grant Morden, M.P., emphasised the cordial reception accorded to the project in Canada, not only from those identified with the enterprise, but from the Government and people of the Dominion. At a dinner given at Ottawa, the Hon. C. M. Ballantyne, Minister of Marine, assured Colonel Grant Morden that the Government of Canada would support most cordially the plans for this Empire development. Colonel Grant Morden, M.P., in response, stated that Canada's real opportunity lay in combining the capital and experience of the Motherland with Canada's own resources. Two things, however, were lacking—capital and experience. Some of the largest steel masters in the United Kingdom were now interested in supplying these to develop the manufacture of steel in Canada. The wisdom of controlling all the fundamental elements of their industry had been proved by the United States Steel Corporation, and in Canada also it was necessary and advisable to include shipping and shipbuilding. In conclusion, Sir Newton Moore pointed out that an amalgamation would bring about economical administration, development, and working of the interlocking submarine areas of the two companies, both as regards coal and ore, with much more efficiency and economy than any possible separate and duplicate developments by the companies individually. Both Sir William Beardmore Bart., and Mr. Benjamin Talbot expressed entire concurrence with the views of Sir Newton Moore, and emphasised the fact that in securing to the country these valuable deposits would place the British Empire in the position of being absolutely independent of outside sources.

Applications for Patents.

Automatic & Electric Furnaces, Limited, and Barfield, E. P. Electric muffle furnaces. 10,299. April 13.

Bain, D. B., and Keith, G. and J. Apparatus for drying moulds. 11,758 April 28.

Bangerter, B. A. Metal alloy. 10,125. April 12.

Beardsley, E. D. Apparatus for making moulds for casting. 10,334. April 13.

Carrick, R., and Stevenson, W. Apparatus for producing sand-cores for metal castings. 10,046. April 10.

Dodgson, A. H. and W., and Trotter, G. W. Manufacture of metal castings. 12,061. April 30.

Dostal, L. Bearings. 12,019. April 30. (Austria, June 17, 1918.)

(Electric Brazing and Welding Company). Wire-winding machines. 11,648. April 27.

Fortified Manufacturing Company. Melting-pot feeder. 10,332. April 13. (United States, October 4, 1916.)

Fortified Manufacturing Company. Heating-device for metal-melting crucibles. 10,333. April 13. (United States, July 18, 1917.)

Lloyd, W. Furnaces. 10,423. April 14. (United States, May 4, 1916.)

Milner, R., and Robinson, T. Manufacture of bricks, blocks, etc., from blast-furnace slag. 10,302 April 13.

Neil, J. M., and Ringrose, F. Dampers of furnace flues, etc. 10,399. April 14.

Nicholson & Sons, J., and Parkes, S. S. Manufacture of hollow steel bars. 5,453. February 23.

Rustproofing Syndicate and Newman, T. F. Coating ferrous metals with non-rusting alloy. 11,107. April 21.

Rustproofing Syndicate and Newman, T. F. Process for prevention of black oxide of iron on ferrous metal forgings, etc. 11,108. April 21.

Schauffelberger, E. Foundry machinery, etc. 6,083. February 28.

Smethurst, E. C. Foundry core support. 10,476 April 15.

Smith, J. L. Device for removing flaws from hot steel billets. 9,928. April 9.

Soc. Metallurgique du Frayol. Electric furnaces. 8,444. March 22. (France, January 7.)

Stock, G. J. Production of metals in electric furnace. 8,719. March 24.

Talbot, B. Metallurgical furnaces. 9,455. April 1.

Tate, W. Method of tempering or hardening tools and tool steels. 11,217. April 22.

U.S. High Speed Steel & Tool Corporation. High-

White, W. A. Furnace fronts. 8,924. March 26.

Williams, H. A. Grates, furnaces, etc. 8,959. March 26.

Wilson Welder & Metals Company. Electrical welding. 9,687. April 6. (United States, April 22, 1919.)

Personal.

The late Mr. J. Hornby, iron and steel merchant, of Bradford, left £34,699

THE late Mr. W. Whittle, iron merchant, of Seascale, Cumberland, left £25,306.

THE late Mr. J. J. King, iron and steel merchant, etc., formerly of Redheugh, Gateshead, left £17,552.

SIR JAMES MCKECHNIE, a director of Vickers, Limited, has left this country for Canada and the United States.

MR. JOSEPH PEASE, of Swale, Richmond, Yorkshire, has joined the board of directors of the Grange Iron Company, Limited, Grange Iron Works, Durham.

THE late Mr. C. Rushworth, founder of Messrs. Rushworth & Company, engineers, Sowerby Bridge, left property of the value of £26,304, of which £20,876 is net personalty.

THE gross value of the estate of the late Mr. J. M. Howie, for many years a director of the Coghlan Steel and Iron Company, Limited, is £13,043, with net personalty £11,822.

MR. A. BONNIN has been elected chairman of the Wallsend Slipway and Engineering Company, Limited, and Mr. W. B. Pickering, of Hadfields, Limited, has been elected to a seat on the board.

MAJOR G. GROVE BLACKWELL has now joined the Compagnie des Alliages, of Paris, as managing director. The company specialises in ferro-alloys, minerals and metals.

MR. S. J. WAVISH, who has retired from the position of shipbuilding manager to Cammell, Laird & Company, Limited, Birkenhead, has been the recipient of a presentation from the officials and men.

MR. F. G. PENNY has resigned his position in R. G. and C. F. Woolwich Arsenal, and is taking up the management of the Phosphor Bronze Company's Birmingham works.

ASSOCIATE-PROFESSOR J. WEMYSS ANDERSON has been appointed by the Council of the University of Liverpool to the John William Hughes Chair of Engineering: Refrigeration.

MR. C. H. BAMBER, chief chemist to John Bowes & Partners, Limited, Marley Hill Collieries and Coke Works, has been the recipient of a presentation from the officials and men on the occasion of his leaving.

MR. C. ARCHER COULSON, who was for many years assistant manager, and succeeded Col. Hawdon as works manager at the Newport Ironworks, has been appointed general manager of the Skinningrove Iron & Steel Works.

Mr. F. Rees, J.P. of Llanelly, secretary of the Llanelly Steel Company, Limited, has been appointed manager, in the place of Mr. Crosby, who was recently appointed manager of the Port Talbot Steel Company, Limited.

MR. A. BRUCE MUIRHEAD, who had been associated with the business of D. Selby Bigge & Co., consulting engineers, Mercantile Chambers, 53, Bothwell Street, Glasgow, for the past 20 years, has become a partner in the firm.

MR. J. RIDER, of Heaton Moor, Stockport, who was manager for Richard Johnson & Nephew, Limited, Manchester, for five years, and who last year joined the board of the Shropshire Iron Company, Limited, has been obliged, for health and family reasons, to terminate his connection with the latter company.

MR. A. GRAY has been elected president of the West of Scotland Iron and Steel Institute, with Mr. W. W. M'Cosh and Mr. E. H. Lewis vice-presidents (in addition to those holding office.) Mr. D. A. MacCalum has been elected hon. treasurer, and Messrs. J. Mitchell, J. M'Whirter, R. S. Wilson, H. Martin, A. Jack, and W. H. Cathcart members of council (in addition to those holding office).

MR. THOMAS CROSBY, until recently manager, and a director, of the Llanelly Steel Company, Limited, has been appointed general manager of the Port Talbot Steel Works, and also the Margam Iron and Steel Works, which are both owned by Baldwins, Limited. Mr. Crosby is still a director of the Llanelly Steel Company, Limited, the Llanelly Foundry and Engineering Company, Limited, in which the Llanelly Steel Company are interested, and also of the Glynbeudy Tinplate Company, Limited, who have an interest in the Llanelly Steel Works.

Deaths.

THE death has taken place suddenly of Mr. C. J. Coleby, of Darlington, who was for many years in the service of Pease and Partners, Limited.

The death is announced at Düsseldorf, in his 79th year, of Herr August Ludwig Spannagel, for 30 years one of the managers of the Phœnix Iron and Steel Company, at Laar, near Ruhrort. Owing to failing health he had resigned his position in 1902.

THE death of Mr. J. Naylor, head of the firm of J. H. Naylor, Limited, brass founders and finishers, etc., of Wigan, recently occurred at his residence, Elm Bank, Trafalgar Road, Wigan. The deceased gentleman, who was 52 years of age, and had been in failing health for some time, was the son of the late Mr. J. H. Naylor, who founded the business more than half a century ago.

MR. S. GARDINER, formerly of Gardiner, Barugh & Jones, iron, steel and tinplate merchants, Waterhouse Lane, Hull, died on April 21 at his residence, "Clifton," York Road, Harrogate, aged 83 years. The deceased gentleman established the business in 1864, and was at subsequent dates joined by Mr. J. J. Barugh and Mr. W. H. Jones, who have continued to carry on the business since his retirement about twenty years ago.

MR. J. W. WALLIS, joint managing director of Drakes, Limited, gas engineers and ironfounders, Halifax, has died at his residence, Field House, Ovenden, aged 51 years. A native of Huddersfield, he served his articles with Messrs. Dempsters, Elland, but since 1891 had been connected with Drakes, Limited. He was a member of the National Board of the Engineers' Federation, and for five years president of the Engineering Employers' Federation for Halifax and district. During the war he acted as chairman of the Halifax Munitions Committee.

MR. J. RICHARDSON, J.P., of Lincoln, died on April 23, in his 79th year. At the age of 14 the deceased gentleman was apprenticed to the engineering trade, and in October, 1864, he became associated with the late Mr. T. Bell in the firm of Robey & Company. In the following year the firm was changed from a limited company into a private concern, with Mr. Richardson and Mr. Bell as managing partners. The partnership continued until 1893, when the present company was formed with the same two gentlemen as managing directors. Mr. Richardson retired from the firm in 1904. He patented many improvements in engine construction.

MR. E. HALL-BROWN, who was well-known in Teesside industrial circles, has recently died. For some time he had been indisposed, but returned to his duties as general manager of Richardson, Westgarths & Company, Limited. He was apparently in his usual health, but was taken seriously ill and died a few hours later at his residence, Hazelhurst, Eaglescliffe. Prior to going to Middlesbrough, about eight years ago, Mr. Hall-Brown carried on business on his own account on the Clyde. As general manager for Messrs. Richardson, Westgarths, he had charge of their works during the war years when the firm made a substantial contribution of marine engines. The deceased gentleman was a member of the council of the Cleveland Institution of Engineers, and a member of the N.E. Coast Institution of Engineers and Shipbuilders, the Institution of Civil Engineers, and the Institution of Naval Architects.

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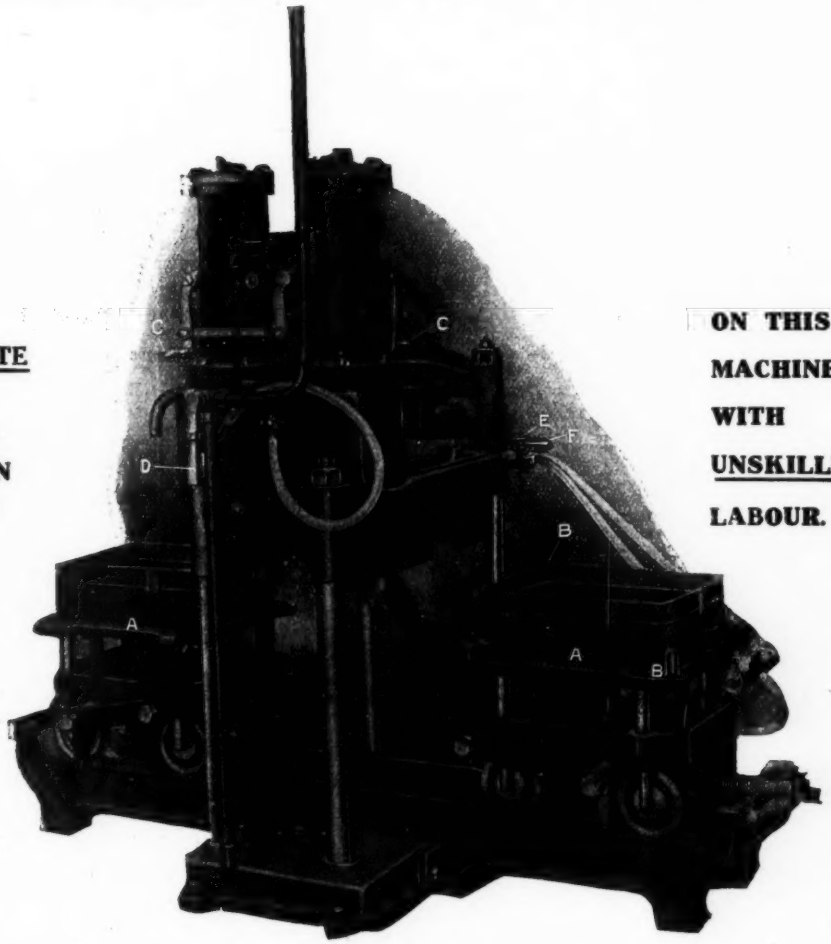
Fitted with self-adjusting Rammer Head which accommodates itself to any varying depth of pattern.

OVER 50 COMPLETE MOULDS PER HOUR HAVE BEEN PRODUCED



ON THIS MACHINE WITH UNSKILLED LABOUR.

One of many that we have installed in various Munition Work Centres.

JAMES EVANS & CO., BRITANNIA WORKS, BLACKFRIARS, MANCHESTER.

New Companies.

Durrants Engineers, Limited.—Capital £5,000 in £1 shares.

Concord Engineers, Limited.—Capital £5,000 in £1 shares.

Improved Steel Company, Limited.—Capital £150,000 in £1 shares.

Widdop Engine Company, Limited.—Capital £100,000 in £1 shares.

Bromac Engineering Company, Limited. — Capital £10,000 in £1 shares.

Northern Rivet & Bolt Company, Limited. — Capital £100,000 in £1 shares.

Aluminium Hollowware Company, Limited.—Capital £5,000 in £1 shares.

Wilson, Macduff & Company, Limited, Ironmasters.—Capital £10,000 in £1 shares.

Fransquet, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers.

Empyrium Welding & Manufacturing Company, Limited.—Capital £5,000 in £1 shares.

Thomas Dudley, Limited.—Capital £8,000 in £1 shares to carry on the business of engineers, etc.

Percy Bennett (Cardiff), Limited.—Capital £1,000 in £1 shares, to carry on the business of ironmasters, etc.

Aubit Tool Syndicate, Limited.—Capital £20,000 in £1 shares. Registered office: 102, Victoria Street, S.W.

A. T. J. Manufacturing Company, Limited.—Capital £3,000 in £1 shares, to carry on the business of engineers.

United Factors, Limited, Engineers.—Capital £10,000 in £1 shares. Registered office: 52 and 53, Snow Hill, Birmingham.

Glacier Metal Company, Limited.—Capital £60,000 in £1 shares. Registered office: Waldo Road, Willesden, N.W.

George Trow, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers. Registered office: 5, Budge Row, E.C.

F. G. Metal Cap & Box Company, Limited. — Capital £10,000 in £1 shares. Registered office: 33a, High Street, Stratford, E.

Reliance Foundry Company, Limited. — Capital £5,000 in £1 shares. Registered office: St. Botolph's Bridge, Peterborough.

Silicate Cement & Engineering, Limited. — Capital £3,000 in £1 shares. Registered office: 101a, Stanhope Street, Birmingham.

Utility Car & Engineering Company, Limited.—Capital £12,000 in £1 shares. Registered office: Craven House, Kingsway, W.C.

Pelabon, Limited.—Capital £250,000 in £1 shares, to take over the business of engineers carried on by C. Pelabon at Twickenham.

Brooks & Doxey (1920), Limited.—Capital £1,000,000 in £1 shares. Registered office: Union Iron Works, West Gorton, Manchester.

Thompson Engineers' Co-operative Society, Limited.—Capital £10,000 in £5 shares. Registered office: Clun House, Surrey Street, W.C.

Stocks (1920), Limited.—Capital £30,000 in £1 shares, to carry on the business of engineers. Registered office: 30, Newland, Lincoln.

Reclamation (South Wales), Limited, Ironmasters.—Capital £150,000 in £1 shares. Registered office: 16, Great George Street, S.W.

Prestwich Auto Engineering Company, Limited.—Capital £5,000 in £1 shares. Registered office: Bury New Road, Prestwich, Lancs.

Unison Foundry Company (Burnley), Limited. — Capital £6,000 in £1 shares. Registered office: Canal Street, off King Street, Burnley.

Deritend Engineering Company, Limited. — Capital £5,000 in £1 shares, to take over the business of T. Bishop, at 45, Deritend, Birmingham.

T. Puplitt, Limited.—Capital £5,000 in £1 shares, to carry on the business of engineers. Registered office: 162, Oxford Road, Manchester.

Western Anglo-Swedish Electric Welding Company, Limited.—Capital £25,000 in £1 shares. Registered office: 25, Mount Stuart Square, Cardiff.

Tofield & Robinson, Limited.—Capital £10,000 in £1 shares, to carry on the business of engineers. Registered office: 165, Edmund Street, Birmingham.

Bradbury Saunders, Limited.—Capital £20,000 in £1 shares, to carry on the business of engineers. Registered office: Glebe Engineering Works, Radcliffe.

S. Barratt & Company, Limited.—Capital £6,000 in £1 shares, to carry on the business of engineers. Registered office: 266, King Street, Hammersmith, W.6.

Charles Hurst & Sons, Limited.—Capital £200,000 in £1 shares, to carry on the business of wire drawers. Registered office: Exchange Mills, Cleckheaton.

Cast Hollow-ware, Limited.—Capital £150,000 in £1 shares, to acquire the shares of Izons & Company, the Bengal Foundry Company, and other companies.

Parkinson & Bottomley, Limited.—Capital £10,000 in £1 shares, to carry on the business of wire drawers. Registered office: Brook House Mills, Cleckheaton.

Taylor & Jones, Limited.—Capital £1,500, to carry on the business of engineers at Huddersfield. Directors: T. H. Lea, R. C. Taylor, and E. T. C. Jones.

John Burtinshaw, Limited.—Capital £20,000 in £1 shares, to carry on the business of sheet metal workers. Registered office: Union Street, Ancoats, Manchester.

Falcon Motor Engineering Company, Limited.—Capital £10,000 in £1 shares (7,000 "A" and 3,000 "B"). Registered office: Singleton Row, Moor Lane, Preston.

Productive British Grinders, Limited.—Capital £2,000 in £1 shares, to carry on the business of machinists, etc. Registered offices: 211, Victoria Road, Aston, Birmingham.

Wilkins & Wright, Limited.—Capital £40,000 in £1 shares (15,000 preferred), to carry on the business of manufacturers of chains and brassfoundry, etc., machinery.

T. Armstrong & Sons, Limited.—Capital £3,000, to carry on the business of boiler makers at Leeds. First directors: J. E. Waterhouse, J. Armstrong, and A. Armstrong.

W. J. Llewellyn, Limited.—Capital £10,000 in £1 shares, to take over the business of an engineer, etc., recently carried on by W. J. Llewellyn at Wellington Foundry, Redditch.

British Zinc Products, Limited.—Capital £25,000 in £1 shares. Directors: F. Jones, H. W. Lloyd, T. R. Jones. Secretary, T. Mills. Registered office: Pipe House Wharf, Swansea.

Alexander Kenyon & Company, Limited. — Capital £15,000 in £1 shares (7,500 pref.), to carry on the business of engineering stores dealers. Registered office: 16, Chapel Street, Salford.

T. C. Enstone & Company, Limited.—Capital £5,000 in £1 shares, to carry on the business of mechanical and general engineers, etc. Registered office: 1-2, Cregoe Street, Birmingham.

Proctor & Pickard (Sheffield), Limited.—Capital £1,500 in £1 shares, to carry on the business of stampers, forgers, etc. Registered office: 36, Burton Road, Neepsend, Sheffield.

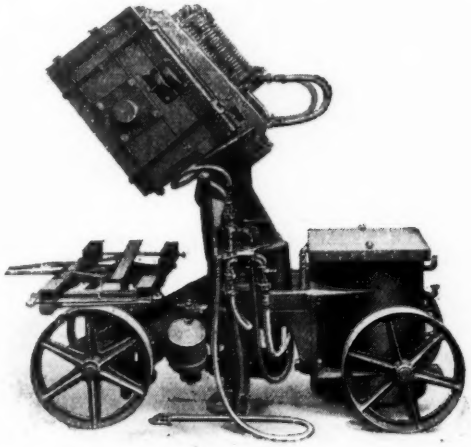
Dick, Kerr & Company, Limited.—Capital £100 in £1 shares, to carry on the business of electrical and general engineers and contractors, etc. Registered office: Queen's House, Kingsway, W.C.

Bell Brothers (Manchester), Limited.—Capital £50,000 in £1 shares (20,000 7 per cent. cumulative preference), to carry on the business of engineers. Registered office: 5, Deansgate, Manchester.

William Whiteley & Sons (Sheffield), Limited.—Capital £6,000 in £1 shares, to carry on the business of shear manufacturers. Registered office: Phœnix Works, 29, Rockingham Street, Sheffield.

Cakemore Bolt, Nut & Manufacturing Company, Limited.—Capital £20,000 in £1 shares. Registered office: Corner of Greens Lane and Nimmings Road, Cakemore, Blackheath, near Birmingham.

MACNAB & CO.



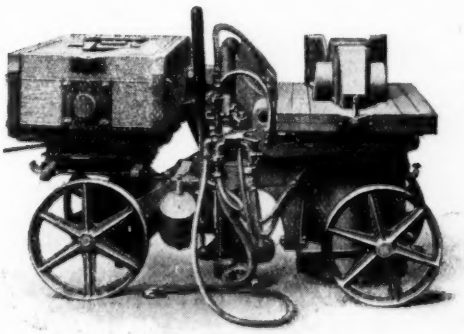
Box and Mould—after being Rammed—in position of being Rolled over

Tabor Patent Portable Combination Shockless Jarring Roll-over AND Pattern-Drawing

MOULDING MACHINE

Capacities and Dimensions furnished upon application.

We make various models and sizes for all types of machine moulding, according to class of work and numbers.



The Finished Mould—showing Pattern after being drawn.

Send us Drawings of your work for Specific Expert Advice, according to your conditions and quantities.

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Works: TOTTENHAM, LONDON, N.17.

F. H. Nevill & Company, Limited.—Capital £3,000 in £1 shares, to carry on the business of mechanical, electrical, and general engineers, etc. Registered office: Oxford Chambers, Victoria Square, Leeds.

F. Brown, Limited (engineers).—Capital £30,000 in 15,000 8¼ cumulative preference and 14,500 ordinary of £1, and 10,000 employés' of 1s. Registered office: Langley Works, Langley Court, Long Acre, W.C.

Vickers-Helvetia, Limited.—Capital £1,000 in £1 shares, to carry on the business of manufacturers of and dealers in steel, iron, etc. First directors: Sir Francis H. Barker, S. V. Dardier, and N. Robinson.

Suffolk Iron Foundry (1920), Limited. — Capital £25,000 in £1 shares, to take over the undertaking and assets of the Suffolk Iron Foundry Company, Limited. Registered office: Prentice Road, Stowmarket.

Eglinton Foundries, Limited.—Capital £200,000 in £1 shares. First directors: A. N. McQuistan, D. Girdwood, V. B. Stewart, and R. McLaren. Registered office: 107, Canal Street, Eglinton, Glasgow.

James Evans & Company (Manchester), Limited.—Capital £35,000 in £1 shares, to carry on the business of foundry engineers. Registered office: Britannia Works, Cross Street, Blackfriars, Manchester.

Tetstall, Howard & Rea, Limited.—Capital £5,000 in £1 shares, to acquire the business of engineers, etc., carried on by W. H. Tetstall, E. G. Howard, and C. V. Rea, at Progress Works, Shrubb Hill, Worcester.

Arthur Howard & Company, Limited.—Capital £10,000 in 7,500 preference shares of £1 and 10,000 ordinary of 5s., to carry on the business of engineers. Registered office: 69, Jamaica Road, Rotherhithe, S.E.

Henry Rossell & Company, Limited.—Capital £101,530 in £1 shares (21,530 preference and 80,000 ordinary), to carry on the business of steel manufacturers. Registered office: Waverley Works, Effingham Road, Sheffield.

David Hyde, Limited.—Capital £5,000 in £1 shares, to carry on the business of manufacturers of furnace, silica, and other sand and fireclay goods. Registered office: Sand Quarry, Hermit Street, Upper Gornal, Staffs.

Standard Electric Welding Company, Limited.—Capital £5,000 in 10s. shares. First directors: J. D. Andrew, W. J. Pickersgill, T. H. Pattinson, T. W. Crozier, and J. H. Readhead. Registered office: Newcastle.

Lawton Tube Company, Limited.—Capital £10,000 in £1 shares, to take over the business carried on by F. H. Jackson, L. H. Jackson, A. H. Lawton, and J. Brookes, at London Road, Coventry, as the Lawton Tube Company.

Edmiston, Brown, & Company, Limited. — Capital £30,000 in £1 shares, to acquire the business of Edmiston, Brown, & Company, mechanical and electrical engineers. Registered office: 219, St. Vincent Street, Glasgow.

Still Engine, Limited.—Capital £300,000 in £1 shares, to adopt agreements with the Engine Development Company, Limited, and with W. J. Still and F. E. Dyke Acland. Registered office: 7, Princes Street, Westminster, S.W.

United Foundry Company, Limited.—Capital £50,000 in £1 shares. First directors: J. King, A. S. Malcolm, A. W. Steven, E. Le Q. Herbert, P. Deas, T. Downie, and J. Fulton. Registered office: 142, St. Vincent Street, Glasgow.

Barbour & Lomax, Limited.—Capital £3,000 in £1 shares, to take over the business of general iron, brass, and metal founders, carried on by J. L. Barbour and E. Lomax, at Wharfe Mill, Bridge Street, Rochdale, as Barbour & Lomax.

Bardsley & Company, Limited.—Capital £3,000 in £1 shares, to carry on the business of engineers, etc. First directors: J. Bardsley (governing director), P. Bardsley, R. Bardsley, and A. Himsworth. Registered office: 27, Fitzwilliam Lane, Sheffield.

Linthorpe-Dinsdale Smelting Company, Limited.—Capital £520,000 in £1 shares, to acquire the existing business. First directors: I. Williams, J. Torbock, P. Williams, M.P., and E. T. John. Registered office: P.O. Buildings, Middlesbrough.

Jovel Engine (England), Limited.—Capital £100,000 in £1 shares, to acquire from the Jovel Engine (Parent) Company the benefit of an existing invention relating to rotary internal combustion engines, etc. Registered office: 17, Waterloo Place, S.W.

Siebe, Gorman & Company, Limited. — Capital £100,000 in £1 shares, to carry on the business of submarine engineers, etc., and to enter into agreement with Siebe, Gorman & Company, Limited. Registered office: 187, Westminster Bridge Road, S.E.

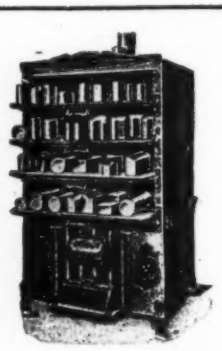
Joseph Waddington & Sons, Limited. — Capital £40,000 in £1 shares, to take over the business carried on at Hindpool Foundry, Barrow-in-Furness, by E. Waddington, E. R. Waddington, J. W. Waddington, and C. C. Waddington, as Joseph Waddington & Sons.

James Brown (Wakefield), Limited.—Capital £10,000 in £1 shares, to take over the business of brassfounders, and finishers, carried on by J. W. Brown, Sarah Brown, Elizabeth Brown, P. Brown, A. Brown, and Lilian R. Brown, at the Central Brass Works, Wakefield, as James Brown.

Nevill Druce & Company, Limited.—Capital £150,000 in £1 shares, to take over the business of smelters of copper, etc., carried on by H. G. Devas, H. Nevill, G. C. Devas, and R. A. Nevill, at Llanelly and at 50, Cornhill, E.C., as Nevill Druce & Company. Secretary: P. W. Jackson.

Wellingboro' Iron Company, Limited. — Capital £500,000 in £1 shares (100,000 preference), to take over the business of the Wellingboro' Iron Company, Limited (incorporated in 1888). First directors: A. McIlwraith, T. P. Harris, G. P. Crane, C. H. C. McIlwraith, and T. C. F. Harris. Secretary: T. Lissmore.

Birmingham Metal Stamping Company, Limited.—Capital £10,000 in £1 shares, to take over the business



THE "PORTWAY"

PORTABLE CORE OVENS

For Gas or Fuel.

TESTIMONIAL.

From The Braintree Castings Co.,
Chapel Hill Foundries, Braintree, Essex.

Gentlemen,

We are very pleased with the Core Oven we recently purchased from you. We find it dries the cores quickly without burning them. It is very handy and economical to use and is altogether superior to other ovens of this type we have in use.

Will you please quote us your best price for four more like it,

Yours faithfully,
For The Braintree Castings Co.,
(Signed) W. B. LAKE, Director.

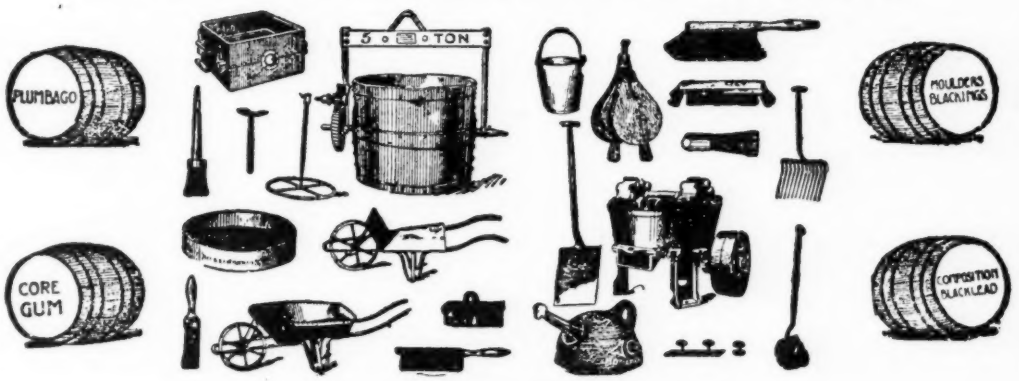
Makers: C. PORTWAY & SON, TORTOISE STOVE & PORTWAY PORTABLE OVEN WORKS, HALSTEAD, ESSEX.

Telephone: 21, Pennistone. Telegrams: "Durrans, Pennistone."

Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.



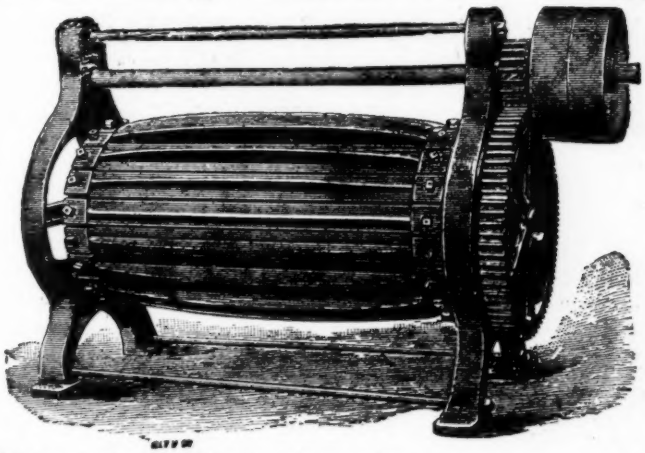
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

carried on by T. W. Coslett at 87, Vittoria Street, Birmingham, as the Birmingham Stamping Company. First directors: T. W. Coslett (permanent) and F. V. Coslett. Registered office: 87, Vittoria Street, Birmingham.

Glamorgan Hematite Iron Ore Company, Limited.—Capital £120,000 in £1 shares, to take over the business of the Cardiff Hematite Iron Ore Company, Limited. First directors: I. Williams, R. Everitt, E. T. John, J. T. Phœnix, and H. W. Martin. Secretary: J. Hutchinson. Registered office: Western Mail Chambers, Cardiff.

William Roman Company, Limited.—Capital £10,000 in £1 shares, to take over the business carried on by G. F. Walker at B16, Queen Insurance Buildings, Liverpool, and to carry on the business of agents for electrical and mechanical engineers, etc. First directors: G. F. Walker (managing director) and D. P. O'Brien.

William Kenyon & Sons (Loxley), Limited.—Capital £15,000 in £1 shares, to take over the business of an iron, steel, and metal roller carried on by W. Kenyon, of the New Rolling Mills, Loxley, near Sheffield. First directors: W. Kenyon, H. Kenyon, and W. Kenyon, jun. Registered office: New Rolling Mills, Loxley, near Sheffield.

Woodall, Duckham & Jones (1920), Limited.—Capital £170,000 (£1—50,000 10 per cent. cumulative preference), to take over the business of Woodall, Duckham & Jones, Limited, consulting, gas, mechanical, electrical, etc., engineers. First directors: Sir A. McDougall Duckham, Sir Wm. J. Jones, and Lt.-Col. H. W. Woodall.

Cranford Ironstone Company, Limited. — Capital £100,000 in £1 shares, to acquire, on the terms of an agreement with the Staveley Coal & Iron Company, Limited, the Parkgate Iron & Steel Company, Limited, and James Oakes & Company, certain ironstone mines at Cranford, near Kettering, etc. Registered office: Staveley Works, near Chesterfield.

Clayton Wagons, Limited.—Capital £1,000,000 in £1 shares (450,000 "original preferred"), to take over the branch businesses of Clayton & Shuttelworth, Limited, relating to the manufacture of steam motor wagons, rolling stock, forgings and drop forgings, etc. First directors: P. W. Robson, A. G. Foster, F. L. Lane, G. Robson, and C. F. Blacklock.

United Electrical Company (Birmingham), Limited.—Capital £5,000 in £1 shares, to take over the business of engineers carried on by G. D. Mann, S. E. Shearman, and F. R. Pendergast, at 47, Summer Row, Birmingham, as the United Electrical Company. Permanent directors: G. D. Mann, S. E. Shearman, and F. R. Pendergast. Registered office: 47, Summer Row, Birmingham.

Franklin Engineering Company, Limited.—Capital £50,000 in £1 shares, to take over the business of an electrical and mechanical engineer, carried on by W. H. Franklin at Tunnel Works, Queen Street, Cardiff, and the business of a scientific instrument maker carried on by T. W. Franklin at 6, North Edward Street, Cardiff, as the Western Instrument Company. Registered office: 233, Cowbridge Road, Cardiff.

Levant Iron & Machinery Company, Limited.—Capital £25,000 18s., in 5,000 6 per cent. cumulative preference shares of £5 each and 18 deferred shares of 1s. each, to carry on at Constantinople and elsewhere the business of importers of and dealers in metals, agricultural implements, etc. First directors: W. J. Whittall and G. A. Chisnell. The Board of Trade authorises the company to acquire parts of the undertakings of J. W. Whittall & Company, Limited, and George Chisnell & Company, Limited. Registered office: 8, Serjeants' Inn, E.C.

ATTAINED AT LAST!

THE

99 % Pure Aluminium

REAL PRESSURE DIE CASTING PLANT

Pressure Die Casting in PURE ALUMINIUM can now be done just as easily as White Metal Die Casting.

The only HEAT CONTROLLED, REAL PRESSURE Die Casting Machine on the WORLD'S MARKET.

Patented in all CIVILISED COUNTRIES under Hall's Patents.

Sole Makers: MONOMETER MFG. CO. (1918) Ltd.,

Manufacturers of all types of Melting, Hardening and Annealing Furnaces.

Ladywood Foundry, Browning Street, BIRMINGHAM.

We can quote for all dies and parts for pressure die casting in White Metal and Pure Aluminium.

WHAT MESSRS. RANSOME & MARLES SAY ABOUT OUR WHITE METAL PRESSURE DIE-CASTING MACHINE—

"To the Monometer Manufacturing Co. (1918) Ltd.,
Browning Street, Birmingham

Dear Sirs,

We have much pleasure in informing you that we have five "Monometer" Die Casting Machines in regular use in our Works, running double shifts, and have found them most satisfactory in operation and excellently suited for producing our Cages economically in large quantities.

We have sent you, under separate cover, a few samples of the latter produced on your machines, and these bear witness to the high class of work produced.

Yours faithfully,
For Ransome & Marles Bearing Co., Ltd.,
(Signed) C. C. RICHARDS,
Assistant Works Manager."

WE SUPPLY **THE** LEADING FIRMS IN THE TRADE WITH

FOUNDRY BLACKINGS

OF ALL KINDS

COAL DUST, CHARCOAL, PLUMBAGO and BLACK-LEAD CORE GUMS and all Foundry Requisites, and have done so since 1831.

I. & I. WALKER, EFFINGHAM MILLS, ROTHERHAM.

Our Specialite is Studying Special Requirements.

KINDLY HAND US YOUR ENQUIRIES.

The Mastery

of the Air.

FANS

SEND US YOUR ENQUIRIES FOR

are always successful in the struggle for the Mastery of the Air

Ventilation of Ships, Buildings and Mines, Induced Draught on Boilers, Dust Removal, High Pressure Fans for Forge Fires and Cupolas, Air Washers for Cooling and Purifying the Air, Fans for Removing Fumes or Steam, Steam Heater Units for Heating Factories and Workshops.

Davidson & Co., Limited, *Sirocco Works,* **BELFAST.**

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,

FIRE CLAY.

Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.

STEEL MOULDERS' COMPOSITION, SILICA CEMENT.

J. GRAYSON LOWOOD & Co., Ltd.,

DEEPCAR nr. SHEFFIELD.

Telegrams: "LOWOOD, DEEPCAR."

MONTHLY PRICE LIST.

The undermentioned prices, unless otherwise specified, are those obtaining at the commencement of the current month.

Pig-Iron.

	Home. £ s. d.
Hematite—	
East Coast Mixed Nos.	13 0 0
East Coast No. 1	13 2 6
West Coast Mixed Nos.	14 15 0
Scottish Mixed Nos.	14 5 0
Welsh Mixed Nos.	14 0 0
Cleveland—	
No. 1	11 10 0
No. 3 foundry G.M.B.	10 17 6
No. 4 foundry	10 17 6
No. 4 forge	10 17 6
Basic	11 7 6
Derbyshire, Leices., and Notts—	
No. 4 forge	11 15 0
No. 3 foundry	12 0 0
No. 2 foundry	12 2 0
No. 1 foundry	12 4 0
Basic	12 0 0
Northamptonshire—	
No. 4 forge	11 10 0
No. 4 foundry	11 11 6
No. 3 foundry	11 12 6
No. 2 foundry	11 14 0
No. 1 foundry	11 15 0
Basic	12 0 0
South Staffordshire, Shropshire and Worcestershire—	
Part-mine forge	12 2 6
Part-mine foundry	12 5 0
Common Staffs.	10 15 0
All-mine forge	12 15 0
All-mine foundry	13 0 0
Warm-air forge	13 12 6
Warm-air foundry	14 2 6
Cold blast	17 0 0
Basic	12 5 0
Scottish—	
Foundry, No. 3	13 5 0
Delivered in Manchester—	
*Derbyshire, No. 3	—
*Cleveland, No. 3	—
*Scottish, No. 3	—

* Merchant prices.

Delivered in Sheffield—	
East Coast hematite	—
Derbyshire basic	—
Lincolnshire basic	—
Do. No. 3 foundry	—
Do. forge	—

High-Speed Tool Steel.

	s. d.
Finished bars, 14 per cent. Tungsten	3 6
Finished bars, 18 per cent. Tungsten	4 3
Per lb. delivered buyers' works.	
Extras—	
Rounds and squares 3 in. to 8 in. inclusive	4d. per lb.
Rounds and squares under ½ in. to ¼ in.	3d. ,,
Flats under 1 in. by ¼ in. to ½ in. by ¼ in., and all sizes over four times 3 in width and over thickness	3d. ,,
Bevels of approved sizes and sections	6d. ,,
If in Coils	3d. ,,
Packing	4s. per cwt
Bars cut to length	10% extra
Scrap from High-Speed Tool Steel—	
Scrap pieces, 5d.	
Turnings and Swarf, 3d.	
Per lb. net, d/d steel-makers' works.	

Ferro-Alloys.

Ferro-Titanium—23/25% Ti. carbonless, 1/10.
Ferro-Tungsten.—75/80%, 3/3.
Ferro-Molybdenum.—70/80%, Mo., 11/-.
Ferro-Vanadium.—35/40%, Va., 60/-.
Metallic-Manganese.—98/99%, carbonless, 4/-. (All per lb.).
Ferro-Phosphorus—20/25%, P. £52 10 0.
Ferro-Chrome.—4/6%, car., £46 0 0.
Ferro-Chrome.—6/8%, car., £44 0 0.
Ferro-Chrome.—8/10%, car., £42 0 0.
Ferro-Chrome—Specially refined, basis 60% chr., max. 2% car., £97 10 0.
Ferro-Silicon.—45/50% Si., £25 0 0 d/d. at Sheffield Steelworks.
Ferro-Manganese.—80%, £37 10 0. loose, £38 10 0 packed. Export £45, according to destination. (All per ton.)

Copper.

	£ s. d.	£ s. d.
Standard cash	95 0 0	95 5 0
Three months	98 10 0	99 0 0
Electrolytic	105 0 0	107 0 0
Tough	103 0 0	104 0 0
Best selected	105 0 0	106 0 0
Sheets	161 0 0	—
India	161 0 0	166 0 0
American electrolytic spot	105 0 0	—
Do. July	105 10 0	106 0 0
Official average price cash, Apr.		103 2 11½
Do. Three months, Apr.		105 17 8½
Do. Settlement, Apr.		103 1 6
Do. Electro. Apr.		112 15 0
Do. B.S., Apr.		111 18 10½
Average spot price, copper, Apr.		103 0 9
Do. Electro, Apr.		111 11 0

Tin.

	£ s. d.	£ s. d.
Cash	274 10 0	275 0 0
Three months	280 0 0	280 10 0
English	273 0 0	274 0 0
Bars	273 0 0	276 0 0
Refined	—	—
Straits	—	296 10 0
Australian		275 10 0
Eastern		284 0 0
Banca		276 0 0
Official average price, cash, Apr.		345 13 10½
Do. Three months, Apr.		344 13 10½
Do. Settlement, Apr.		345 12 3
Average spot price, Apr.		345 9 0

Spelter.

	£ s. d.	£ s. d.
Ordinary	44 0 0	—
Remelted	26 0 0	38 0 0
Hard	29 0 0	30 0 0
Electro 90,9	48 0 0	49 0 0
English	46 10 0	—
India	38 0 0	40 0 0
Zinc dust	50 0 0	55 0 0
Do. English	—	—
Zinc ashes, per cent. 70%	11 0 0	12 0 0
Official average price, Apr.		48 9 4½
Average spot price, Apr.		47 7 9

Lead.

Soft foreign (net)	39 0 0
English	41 10 0
Official average price, Apr.	40 4 0
Average spot price, Apr.	39 4 6

Antimony.

English regulus	65 0 0 68 0 0
Chinese	56 0 0 57 0 0
Crude	43 0 0 44 0 0
Ore	Nominal.

Aluminium.

Virgin Metal 98/99—, per ton. 165 0 0

Phosphor Bronze.

Ingots.	Per ton.
Alloy No. I. or II.	—
III., IV., or V.	—
IV. or VII	—
VIII.	—
XI.	—
Cast Strips and Ingots	—
Castings.	**Per lb.**
I. or II.	—
III., IV. or V.	—
IV. or VII.	—
VIII.	—
XI.	—
No. VII., Chill, Cast, Solid	—
,, Cored Bars	—

Delivery 2 Cwt. free to any town.
10 per cent. Phosphor Copper price of best selected copper. £40 above
15 per cent. Phosphor Copper price B.S. £50 above
Phosphor Tin (5 per cent.) price of English Ingots. £30 above

Phosphor-bronze prices supplied by CHARLES CLIFFORD AND SON, LIMITED, FAZELEY STREET MILLS, BIRMINGHAM.

*Chromium (Metallic).

98/99— purity, per lb. 7/6

*Nickel.

In cubes, 98/99— purity per ton £230 0 0

Nickel Silver.

	per lb.
Ingots for raising	1/7 - 2/-
Ingots for Spoons and Forks	1/7 - 2/-
,, rolled to spoon size	1/10 - 2/3

*Tungsten Metal Powder.

	per lb.
96/98— purity	3/9

*Molybdenum Metal.

96/98— purity, per lb —

*Cobalt Metal.

97— purity, per lb. £ 0 13 0

Quicksilver.

75 lb. bottle £ 17 15 0

* Net, delivered Sheffield Works.

Scrap Iron and Steel.

Cleveland.	s. d.	£ s. d.
Steel scrap, heavy melting	—	200 0
Iron scrap cast (cupola metal)	—	200 0
(London f.o.b.).		
Heavy steel		—
Light ,,		—
Heavy cast		—

Steel Scrap.	Per ton. £ s. d.
Without Analysis—	
Heavy steel melting scrap	10 5 0
Steel planings, turnings and borings	9 5 0
Steel planings, turnings and borings mixed with wrought-iron or other material	9 0 0
Other classes of steel scrap, whether or not mixed	9 5 0
F.o.r. or in barge at nearest siding or wharf.	
With Analysis—	
Heavy steel melting scrap not over 0.04 per cent. p. and s.	10 10 0
Heavy steel melting scrap not over 0.05 per cent. p. and s.	10 10 0

Wrought-Iron Scrap.

	£ s. d.
(1) (a) W.I. plates and sections, not less than ¼ in. thick, reasonably clear of rivets, flanged ends, etc., suitable for shearing; cable scrap and chain scrap not less than ½ in. dia.	11 5 0
(b) Heavy W.I. scrap not less than ¼ in. thick including horseshoes, rivets and bolts, and scrap therefrom	11 5 0
(c) W.I. scrap under ¼ in. thick, and all W.I. scrap not included in classes 1, 2 and 3	11 5 0
(2) Mixed W.I. scrap	9 15 0
(3) Wrought-iron planings, turnings and borings mixed with steel or other materials	8 5 0
(4) W.I. planings, turnings and borings	8 7 6

Cast-Iron Scrap.

	£ s. d.
Heavy ord., broken, between 1½ cwt. and 10 cwt. each	10 5 0
Heavy machinery, broken between 1½ cwt. and 10 cwt. each	10 10 0
Cold blast, broken, between 1½ cwt., and 10 cwt.	12 5 0
Ingot mould, unbroken	11 10 0
Do. broken, between 5 cwt. and 2 tons each	11 15 0
Do. between 1½ cwt. and 5 cwt. each	12 0 0
Railway chairs, whole or broken for remelting	10 10 0
Heavy lumps, not exceeding 2 tons each	10 2 6
Light	9 15 0
Burnt, broken ready for cupola	9 0 0
Burnt fire bars	9 10 0
Turnings and borings, for iron and steel makers	10 0 0

Old Metal.

	£ s. d.
London—	
Copper (clean)	80 0 0
Brass (clean)	52 0 0
Lead (less usual draft)	32 0 0
Tea lead	30 0 0
Zinc	26 0 0
New aluminium cuttings	120 0 0
Brazlery copper	67 0 0
Gunmetal	70 0 0
Hollow pewter	230 0 0
Shaped black pewter	120 0 0
(Above all d.d merchant's yard).	

Metallurgical Coke.

	£ s. d.
Durham and Northumberland—	
Blast furnace	3 2 9
Foundry	3 10 0
Lancs., Staffs., Yorks, Notts., Derbyshire, Lincolnshire and Midland Counties—	
Blast furnace	3 5 9
Foundry	3 17 9
F.o.t. at ovens.	